State of New York—Department of Agriculture

TWENTY-FOURTH ANNUAL REPORT

OF THE

BOARD OF CONTROL

OF THE

NEW YORK

Agricultural Experiment Station

(GENEVA, ONTARIO COUNTY)

FOR THE YEAR 1905

With Reports of Director and Other Officers

TRANSMITTED TO THE LEGISLATURE JANUARY 15, 1906

ALBANY
BRANDOW PRINTING COMPANY
1906

STATE OF NEW YORK.

No. 61.

IN ASSEMBLY,

JANUARY 15, 1906.

TWENTY-FOURTH ANNUAL REPORT

OF THE

Board of Control of the New York Agricultural Experiment Station.

STATE OF NEW YORK:

DEPARTMENT OF AGRICULTURE,

ALBANY, N. Y., *January* 15, 1906.

To the Assembly of the State of New York:

I have the honor to herewith submit the Twenty-fourth Annual Report of the Director and Board of Control of the New York Agricultural Experiment Station at Geneva, N. Y., in pursuance of the provisions of the Agricultural Law.

I am, respectfully yours,

CHARLES A. WIETING,

Commissioner of Agriculture.

NEW YORK AGRICULTURAL EXPERIMENT STATION.

GENEVA, N. Y., *January* 1, 1906.

Hon. CHARLES A. WIETING, *Commissioner of Agriculture, Albany, N. Y.:*

Dear Sir.—I have the honor to transmit herewith the report of the Director of the New York Agricultural Experiment Station for the year 1905, in accordance with the provisions of chapter 439, Laws of 1904.

Yours respectfully,

S. H. HAMMOND,

President, Board of Control.

1905.

ORGANIZATION OF THE STATION.

BOARD OF CONTROL.

GOVERNOR FRANK W. HIGGINS, Albany.
COMMISSIONER CHARLES A. WIETING, Albany.
STEPHEN H. HAMMOND, Geneva.
LYMAN P. HAVILAND, Camden.
EDGAR G. DUSENBURY, Portville.
THOMAS B. WILSON, Halls Corners.
MILO H. OLIN, Perry.
IRVING ROUSE, Rochester.
CHARLES W. WARD, Queens.

OFFICERS OF THE BOARD.

STEPHEN H. HAMMOND, *President.*

WILLIAM O'HANLON, *Secretary and Treasurer.*

EXECUTIVE COMMITTEE.

STEPHEN H. HAMMOND, LYMAN P. HAVILAND, THOMAS B. WILSON.

STATION STAFF.

WHITMAN H. JORDAN, Sc. D., *Director.*

GEORGE W. CHURCHILL, *Agriculturist and Superintendent of Labor.*
WILLIAM P. WHEELER, *First Assistant (Animal Industry).*
FRED C. STEWART, M. S., *Botanist.*
HARRY J. EUSTACE, B. S., *Assistant Botanist.*
[0]HENRY J. RAMSEY, M. A., *Student Assistant in Botany.*
LUCIUS L. VAN SLYKE, Ph. D., *Chemist.*
EDWIN B. HART, B. S., *Associate Chemist.*
[11]WILLIAM H. ANDREWS, B. S.,
[2]FREDERICK D. FULLER, B. S.,
[5]CHARLES W. MUDGE, B. S.,
[13]ANDREW J. PATTEN, B. S.,
[1]FRANK A. URNER, A. B.,
[3]ERNEST L. BAKER, B. S.,
[4]ALFRED W. BOSWORTH, B. S.,
[6]WILLIAM E. TOTTINGHAM, B. S.,
[7]ARTHUR W. CLARK, B. S., *Assistant Chemists.*
HARRY A. HARDING, M. S., *Bacteriologist.*
MARTIN J. PRUCHA, Ph.B., *Assistant Bacteriologist.*
GEORGE A. SMITH, *Dairy Expert.*
FRANK H. HALL, B. S., *Editor and Librarian.*
PERCIVAL J. PARROTT, M. A., *Entomologist.*
HAROLD E. HODGKISS, B. S., *Assistant Entomologist.*
[8]WILLIAM J. SCHOENE, B. Agr., *Student Assistant in Entomology.*
[9]SPENCER A. BEACH, M. S.,
[10]ULYSSES P. HEDRICK, M. S., *Horticulturists.*
NATHANIEL O. BOOTH, B. Agr., *Assistant Horticulturist.*
ORRIN M. TAYLOR, *Foreman in Horticulture.*
[12]F. ATWOOD SIRRINE, M. S., *Special Agent.*
FRANK E. NEWTON,
JENNIE TERWILLIGER, *Clerks and Stenographers.*
ADIN H. HORTON, *Computer and Mailing Clerk.*
JULIA A. HOEY, *Junior Clerk.*

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[0] Resigned June 24, 1905. [1] Resigned January 9, 1905. [2] Resigned May 1, 1905. [3] Appointed May 8, 1905. [4] Appointed May 15, 1905. [5] Resigned June 1 1905. [6] Appointed June 1, 1905. [7] Appointed July 1, 1905. [8] Appointed August 5, 1905. [9] Resigned September 1, 1905. [10] Appointed August 1, 1905. [11] Died September 29, 1905. [12] Address, Riverhead N. Y. [13] Resigned July 1, 1905.

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TWENTY-FOURTH ANNUAL REPORT

OF THE

Board of Control of the New York Agricultural Experiment Station.

TREASURER'S REPORT.

GENEVA, N. Y., *October* 1, 1905.

To the Board of Control of the New York Agricultural Experiment Station:

As Treasurer of the Board of Control, I respectfully submit the following report for the fiscal year ending September 30, 1905:

NECESSARY EXPENSE.

Receipts.

1904.		APPROPRIATION 1904—1905.	*Cr.*
Oct.	1.	To balance on hand	$26 83
		Amount received from Comptroller	16,000 00
			$16,026 83

Expenditures.	*Cr.*
By building and repairs	$787 40
By chemical supplies	354 83
By contingent expenses	2,364 63
By feeding stuffs	1,637 98
By fertilizers	290 58
By freight and express	470 13
By furniture and fixtures	928 06
By heat, light and water	125 15

			Cr.
		By library	$853 70
		By live stock	137 00
		By postage and stationery	865 89
		By publications	3,690 27
		By scientific apparatus	28 48
		By seeds, plants and sundry supplies	1,400 77
		By tools, implements and machinery	890 11
		By traveling expenses	1,181 85
1905.			
Oct.	1.	By balance	20 00
			$16,026 83

GENERAL EXPENSE.

HEAT, LIGHT, WATER, APPARATUS, REPAIRS, ETC.

1904.		*Receipts.*	*Dr.*
Oct.	1.	To amount received from Comptroller	$4,000 00

		Expenditures.	*Cr.*
		By building and repairs	$673 19
		By contingent expenses	137 25
		By feeding stuffs	97 01
		By furniture and fixtures	432 00
		By heat, light and water	2,409 62
		By postage and stationery	24 95
		By seeds, plants and sundry supplies	47 37
		By tools, implements and machinery	134 10
1905.			
Oct.	1.	By balance	44 51
			$4,000 00

HORTICULTURAL INVESTIGATIONS,

1905—1906.

Receipts.	*Dr.*
To amount received from Comptroller	$8,000 00

1905.		*Expenditures.*	*Cr.*
		By chemical supplies	$2 75
		By contingent expenses	1,129 46
		By fertilizers	124 79
		By freight and express	14 28
		By postage and stationery	4 45
		By publications	849 36
		By salaries	5,050 74
		By seeds, plants and sundry supplies	333 68
		By tools, implements and machinery	57
		By traveling expenses	483 70
1905.			$7,993 78
Oct.	1.	By balance	6 22
			$8,000 00

COMMERCIAL FERTILIZERS.

1904.		*Receipts.*	*Dr.*
Oct.	1.	To balance on hand	$5,035 39
		To amount received from Comptroller	7,000 00
		To amount due from Comptroller	3,000 00
			$15,035 39

Expenditures.	*Cr.*
By building and repairs	$24 81
By chemical supplies	617 16
By contingent expenses	43 20
By feeding stuffs	25
By fertilizers	3 35
By freight and express	248 31
By furniture and fixtures	2 77
By heat, light and water	643 87
By postage and stationery	36 43
By publications	571 98
By salaries	6,869 66
By seeds, plants and sundry supplies	44 40

			Cr.
		By tools, implements and machinery....	$160 00
		By traveling expenses.................	963 80
1905.			
Oct.	1.	By balance	4,805 40
			$15,035 39

CONCENTRATED FEEDING STUFF INSPECTION.

APPROPRIATION 1904—1905.

1904.		*Receipts.*	
Oct.	1.	To balance on hand....................	$343 04
		To amount received from Comptroller..	3,500 00
			$3,843 04

Expenditures.

		By chemical supplies	$57 42
		By contingent expenses	2 50
		By freight and express................	82 51
		By heat, light and water..............	75 87
		By postage and stationery.............	17 50
		By publications	509 54
		By salaries	1,907 82
		By scientific apparatus	45
		By seeds, plants and sundry supplies...	1 40
		By traveling expenses	605 73
1905.			
Oct.	1.	By balance	582 30
			$3,843 04

SALARIES.

APPROPRIATION 1904—1905.

1904.		*Receipts.*	*Dr.*
Oct.	1.	To balance	$1,746 24
		To amount received from Comptroller...	22,000 00
			$23,746 24

		Expenditures.	*Cr.*
		By salaries	$22,318 78
1905.			
Oct.	1.	By balance	1,427 46
			$23,746 24

Labor.

appropriation 1904—1905.

1904.		*Receipts.*	*Dr.*
Oct.	1.	To balance	$1,618 36
		To amount received from Comptroller...	13,000 00
			$14,618 36

1904-1905.		*Expenditures.*	*Cr.*
		By labor	$13,339 05
1905.			
Oct.	1.	By balance	1,279 31
			$14,618 36

Insurance Money.

1904.			*Dr.*
Oct.	1.	Balance	$187 07
1905.			*Cr.*
Oct.	1.	Balance	$187 07

Carriage House and Horse Stable.

appropriation 1904—1905.

Receipts.	*Dr.*
To amount received from Comptroller...	$1,923 00

Expenditures.	*Cr.*
By construction	$1,923 00

STORAGE BUILDING.

APPROPRIATION 1904—1905.

Receipts.	*Dr.*
To amount received from Comptroller...	$4,393 00

Expenditures.	*Cr.*
By construction	$4,393 00

All expenditures are supported by vouchers approved by the Auditing Committee of the Board of Control and have been forwarded to the Comptroller of the State of New York.

	Dr.
To receipts from the Treasurer of the United States as per appropriation for fiscal year ended June 30, 1905, as per Act of Congress approved March 3, 1887	$1,500 00

	Cr.
By salaries	$1,485 29
By postage	14 71
	$1,500 00

WILLIAM O'HANLON,
Treasurer.

DIRECTOR'S REPORT FOR 1905.

To the Honorable Board of Control of the New York Agricultural Experiment Station:

GENTLEMEN.—I have the honor to submit the following report of the institution under your charge for the year 1905. In presenting this report it gives me sincere pleasure to express my warm appreciation of the helpful attitude of sympathy and wise support which you have steadily maintained toward me as your executive officer.

It is no less gratifying to again record my sense of obligation to the members of the Station staff for their most earnest and loyal co-operation in carrying on the work of the Station. My associates share generously with me the responsibilities attending our efforts. It has for some years been the policy of this institution to grant to the members of the staff, especially to the heads of departments, large liberty in initiating and maintaining those lines of work which seem likely to be most fruitful of beneficial results. That this policy has justified itself I am firmly convinced. Indeed, in no other way can there be secured the atmosphere of freedom and inspiration so essential to scientific inquiry.

CHANGES IN THE STATION STAFF.

In no year during the life of the Station have the changes in the staff been so numerous, and in no year more important. The larger number of changes have occurred in the Chemical Department, in fact these have been so many as to cause more or less embarrassment.

It is my painful duty to record here the death of Mr. W. H. Andrews, a member of the chemical staff, which occurred at his home in Geneva on September 29th. Mr. Andrews first became connected with the Station in 1891 and had been in its service continuously since October 1st, 1895. Not long previous to his last illness he was placed in immediate charge of the analytical work performed for the Commissioner of Agriculture in the inspection of fertilizers and feeding stuffs. Faithfulness and efficiency characterized Mr. Andrews' work no less emphati-

cally than the qualities of a high-minded gentleman characterized his everyday life and his relations to his associates. His death has brought to all his co-workers a sense of deep personal loss.

Prof. S. A. Beach severed his connection with the Station on September 1st, because of his acceptance of a call to the chair of Horticulture in the Iowa Agricultural College. During his fourteen years of service as head of the Horticultural Department, Prof. Beach gained the attention of the fruit interests of New York to an unusual degree. Such confidence was placed in his conservative and well-guarded utterances that his advice had without question come to exert a marked and highly beneficial influence upon the horticultural practice of the State. Prof. Beach's period of service was brought to a fitting close by his authorship of "The Apples of New York," which is the most notable pomological publication of recent years. Horticultural education in Iowa is certainly much strengthened by the acquisition of Prof. Beach, for whom his friends and recent associates wish the most abundant success in his new field of labor.

Mr. F. D. Fuller, for nearly nine years connected with the chemical work of the Station, received a well earned promotion to larger responsibilities and salary by his appointment to a position in connection with the Pennsylvania Department of Agriculture, the duties of which he assumed on May 15th, 1905.

The Station was further honored by the selection of Mr. A. J. Patten to become the chief chemist of the Michigan Agricultural Experiment Station. Mr. Patten's experience as a chemist in two experiment station laboratories, a year of advanced study in Germany and recent association with important lines of research have rendered him well fitted to enter successfully upon the work of investigation.

Upon request of the Commissioner of Agriculture, Mr. Charles W. Mudge, Assistant Chemist, was transferred to the Department of Agriculture on June 1st. Mr. Mudge's connection with the Station covered something more than six years, during which time he applied himself diligently to the duties that were assigned to him.

Mr. F. A. Urner, Assistant Chemist, after less than two years' service, resigned his position on January 9th, 1905, to take up chemical work along commercial lines.

The position vacated by Prof. Beach has been filled by the selection of Prof. U. P. Hedrick, M. S. Prof. Hedrick comes to us from the Michigan Agricultural College, of which institution he is a graduate and in which he served for six years as Assistant Professor or full Professor of Horticulture. He had previously held positions as Inspector of Orchards and Nurseries in Michigan and as Professor of Botany and Horticulture in the agricultural colleges of Oregon and Utah. The wide acquaintance with the facts and principles of horticulture possessed by Prof. Hedrick, his extended opportunities for practical observation and his experience as a public speaker, designated him as peculiarly fitted to lead the horticultural activities of the Station.

The vacancies in the chemical department have been filled by the choice of Mr. Ernest L. Baker, B. S., a graduate of the University of Maine, and at the time of his election a post graduate student in Columbia University; Mr. Alfred W. Bosworth, B. S., a graduate of the Rhode Island College of Agriculture and Mechanic Arts, and later a student for a time at Yale University, who when called to Geneva was serving as Chemist at the Storrs (Conn.) Agricultural Experiment Station; Mr. William E. Tottingham, a graduate of the Massachusetts Agricultural College, who subsequent to his graduation served his Alma Mater first as Assistant Chemist to the Experiment Station and later as Instructor in chemistry; and Mr. Arthur W. Clark, a graduate of the University of Vermont who previous to accepting his present position was assistant chemist in the Pennsylvania Agricultural Experiment Station.

THE GROWTH OF THE STATION AND ITS NEEDS.

During the past ten years there has been a gradual, and in the aggregate, a large growth of the Station equipment and work. There has not been a corresponding increase of maintenance funds and the time has now come when the question of the further development of the Station's activities, indeed the maintenance of the work it is now doing, must receive your serious consideration.

A few comparisons will serve to set forth the situation as it now exists.

In 1896 the science staff numbered fourteen (14) as against twenty-two (22) at the present time, an increase of fifty-seven per ct. During this period the clerical staff has doubled.

Since 1896 there have been erected the Biological and Dairy building, the Director's house, 1 large forcing-house and 2 poultry houses. The barns of the institution have been built entirely new because of the destruction of the old ones by fire; the building occupied by the offices and library has been entirely remodeled inside, and the head house at the forcing-house has been enlarged.

In its capacity for carrying on various lines of scientific inquiry, the building equipment is more than doubled, involving a large addition to the cost of maintenance, one item of which is the addition of three to the force of janitors and caretakers.

It can not be accurately said that ten years ago the work of the institution was divided into departments, although the investigations then carried on fell, in a general way, under the heads of chemical and horticultural work. The Station has now six well-defined and fairly well-equipped departments, viz.: animal husbandry, bacteriology, botany, chemistry, entomology and horticulture. There has also also been added to the staff an officer known as Editor and Librarian, the first of the kind in any Station in the country. In consequence of this enlargement of the Station staff and the definite division of the work into departments, the investigations carried on have broadened in scope, and it is believed, increased in thoroughness, therefore in expensiveness. This growth has in no sense been forced but has simply been a response, though an insufficient one, to the demand made upon the Station.

The list of names to which the Station publications are mailed has trebled since 1895, thus greatly adding to the printing bills.

Such an enlargement of the salary list, material equipment and work of an institution ordinarily involves a corresponding increase of maintenance funds. As previously stated, this has not occurred. For the fiscal year 1895-6, the maintenance funds outside of the support of inspection work, amounted to $59,500 and for 1905–6 the sum is $64,500, an increase of only $5,000. But since the $10,000 applied to the inspection of fertilizers was formerly appropriated by the State from the general treasury funds and is now secured from license fees imposed on brands of fertilizers, it is really costing the State $5,000 less annually to maintain the Station than it did ten years ago, notwithstanding the large growth of the institution. These facts indicate that it is certainly true that your Board has persistently, and it would

seem successfully, endeavored to economically administer the funds committed to its care. But the limit of economy is now reached and the State is now face to face with the question either of abandoning the policy of further developing the Station to meet existing needs or of supplying increased maintenance funds.

There are two lines of effort in which the members of the Station staff are engaged: 1, The scientific study of problems, largely by laboratory methods, involving the determination of unknown principles and facts which are believed to be fundamental to agricultural practice; 2, the determination of the economic applicability to agricultural technics and practice of such principles and facts as the Station discovers. Experience has demonstrated that the same man cannot effectively prosecute both lines of endeavor in an extensive way. The botanist, for instance, cannot successfully conduct laboratory researches with plant diseases and at the same time be responsible for the personal supervision of field experiments. An absorption of mind and continuity of effort essential to scientific research should not be disturbed by frequent and extended absences for excursions about the State. Efficient organization requires that field work and other practical demonstrations should be assigned to men who are able to give to them their undivided attention, and the same is true of the efforts that are more distinctively scientific or investigational. At the present time the Station force is not adequate to the prosecution of such investigations and such outdoor demonstrations as seem to be demanded of us. I therefore most earnestly recommend that you endeavor to secure such financial support as shall enable us to enlarge our force so that the present members of the staff may give greatly increased time to the problems which are pressing upon us for solution.

Fundamentally this is a question of expediency. Which policy will the better serve the interests of New York Agriculture? Would it be profitable to further enlarge the work of the Station? Certainly the Station is unable to accept more than a small minority of the opportunities that come to it for the study of important problems. It is equally certain that the agricultural practice of the State has by no means fully adopted the advanced methods which the Station's investigations have been the means of suggesting. It may easily be demonstrated that the work of the Station has in the past been highly productive

and there is every reason to believe that it may be largely increased with equal profit.

HOUSES FOR THE STATION STAFF.

Attention is again called to the great desirability of erecting more houses for the use of members of the Station staff. In presenting the reasons for this recommendation I cannot do better than to quote from my report for 1904: "The building equipment of the Station now provides for the housing of five families belonging to the Station staff. Under the conditions at present prevailing the homes of the staff are widely scattered. The married members, other than those provided for on the Station grounds, live in various parts of the city in rented houses. There is involved in this arrangement a great deal of uncertainty as to permanence and desirability of location. It is also often inconvenient; and under such conditions it is exceedingly difficult and almost impossible to maintain that social unity which should prevail at such an institution and which is a large factor in its spirit and success. The desirability and attractiveness of any salaried position are to a very large degree determined by social relations and by the environment and influences which surround the home. In view of the fact that there is an almost continuous effort to draw away from the Station its best men, sometimes successfully, it would seem to be a good policy to do all that is possible to render positions at the Experiment Station so attractive that efficient and useful men shall not be drawn away. It is fair to raise the question, therefore, whether, if it is not inconsistent with the established policy of the State, several more houses should not be erected on the Station grounds, sufficient in number at least to accommodate the heads of departments and certain minor officials whose presence near the Station at all times is very essential."

MAINTENANCE FUND.

The various funds that were appropriated by the Legislature of 1905, for the maintenance of the Station during the fiscal year beginning October 1, 1905, were as follows:

Salaries	$23,000
Labor	13,000

Expenses of various departments of research........	$15,000
General expense, heat, light, water, apparatus, repairs, etc.	4,000
Expenses of horticultural investigation..............	8,000
Fertilizer inspection	10,000
Feeding stuff inspection	3,500

By action of your Board, the Legislature is asked to appropriate the following sums for the fiscal year beginning October 1, 1906:

Salaries	$33,000
Labor	14,000
Expenses of various departments of research........	26,000
General expense, heat, light, water, apparatus, repairs, etc.	5,000
Expenses of horticultural investigation..............	10,000
Fertilizer inspection	10,000
Feeding stuff inspection	3,500

STATION PUBLICATIONS.

The Station mailing list, including 2,000 copies of the Annual Report, now requires sending out approximately 48,000 single copies of our publications. As stated elsewhere, this is not far from three times the number mailed in 1895. This larger use of our literature has come about almost entirely through requests which have been received at my office. There has been no padding of the mailing list.

It is gratifying to note that the results of our work are receiving increased attention not only on the part of intelligent farmers but also from professional men and teachers. Requests have been received for our publications, from the professors in one of our oldest universities that has no specific relation to agricultural education and from the principals of high schools, with a view to using this material in the class rooms and science laboratories. Members of the medical profession have commented favorably on the results of our chemical and biological investigations of milk and cheese as contributing directly to a knowledge of certain phases of human nutrition. All this illustrates the

fact that knowledge useful to the farmer is broadly related to all human needs and activities. A better understanding of the air, the soil and plant and animal life, serves to strengthen man's mastery of the earth, in whatever calling. It is entirely rational that our urban population should come to understand and support the work of the agricultural experiment station as directly contributory to the welfare of all classes of persons. The city family has reason to thank modern science, largely applied to agriculture through Station effort, for better fruit and vegetables and for more palatable and more healthful dairy products.

The distribution of the information given out by the Station is by no means confined to reports and bulletins. These simply state principles and facts which are used by the press, and by institute speakers before hundreds of farmers, and when illustrated by progressive farmers are the basis of a more or less contagious example to every other farmer in the surrounding communities.

"THE APPLES OF NEW YORK."

This publication, in two volumes, was announced in my report for 1904. The first volume is now being distributed. In order that the public may fully understand the sources of supply it should be stated that of 19,000 copies ordered printed, 2,000 copies are assigned to the Station, 2,000 to the Commissioner of Agriculture and 15,000 copies are placed at the disposal of the members of the Legislature. The Station supply is being largely drawn upon by our official list and by several hundred correspondents who aided in supplying data. These facts will serve to explain the inability of the Station to comply with all the requests that we have received for these volumes.

The approval which this publication is receiving from all quarters is most gratifying and encourages the hope that the State will be willing to meet the expense of similar publications for other fruits. The Station has collected at great cost, extensive data relating to peaches, pears, plums and grapes. Such a mass of facts is too valuable to lie unused. It is now time that plans should be formulated for publishing this material, the preparation of all of which will require not less than five or six years. I commend to your favorable consideration the suggestion that, if funds can be provided, an editorial staff be secured in the near

future for the preparation of this valuable material for publication under the supervision of the Station Horticulturist. It is out of the question for the regular horticultural staff to do this work without dropping all other efforts, a situation hardly to be tolerated in a department so closely in touch with the extensive fruit interests of the State.

THE MAILING LIST.

Since January 1, 1905, approximately three thousand and eight names have been added to our mailing list:

Bulletin Lists, December 15, 1905.

Popular Bulletins.

Residents of New York	35,000
Residents of other States	2,215
Newspapers	780
Experiment stations and their staffs	1,154
Miscellaneous	131
Total	39,280

Complete Bulletins.

Experiment stations and their staffs	1,154
Libraries, scientists, etc	170
Foreign list	234
Individuals	2,915
Miscellaneous	131
Total	4,604

DEMONSTRATION EXPERIMENTS.

The Station still continues to maintain in numerous places in the State experiments having for their object the determination of the applicability of certain methods to agricultural practice. The lines of work and the localities in which the experiments are located are given below. It is a pleasure to acknowledge the efficient aid which the Station is receiving at the hands of the various persons mentioned in the following list:

Study of Cabbage Rot.

W. A. Fleet............Cutchogue.

Prevention of Red Spot in Cheese.

E. L. Carpenter............Russia.

Treatment of Asparagus Rust.

F. A. Sirrine............Riverhead.

Spraying for Potato Blight.

Brainerd & Beaumont...Gainesville.

Spraying for Potato Blight—(Con.)

J. S. Burke................Syosset.
D. Clark......................Peru.
T. S. Darling..............Atlanta.
P. S. Doolittle............Cassville.
F. E. Gott.............Spencerport.
George H. Hyde...........Cortland.
E. E. Halsey........Bridgehampton.
F. G. Rathbun........Verona Mills.
E. T. Ryder..............Gowanda.
W. H. Satterly..........Mattatuck.
W. R. Shaw................Hebron.
Oliver Smith & Son.....Chateaugay.
Taylor Bros...............Arkport.

Tests of Sulphur Washes.

A. H. Dutton..........Youngstown.
Alfred Lewis..................Geneva.
H. H. Loomis..............Geneva.
Israel Luce..............Northville.
John Maney................Geneva.
T. C. Maxwell & Bro........Geneva.
Elihu S. Miller.......Wading River.
Rice Bros..................Geneva.
C. K. Scoon................Geneva.
Gilbert Scudder.........Huntington.
F. A. Sirrine............Riverhead.
Frank Stevens..............Geneva.
White & Rice............Yorktown.

Tests of Sulphur Washes—(Con.)

Sophie M. Woodhull.........Laurel.
W. H. Woolworth......Youngstown.

Control of Bud Mite.

W. P. Rogers...........Williamson.

Experiment with Grape Stocks.

I. A. Wilcox..............Portland.

Orcnard Management.

W. D. Auchter........South Greece.
Grant Hitchings............Syracuse.

Economy of Dwarf Orchards.

F. E. Dawley..........Fayetteville.
Albert Wood & Son..Carlton Station.
Edward Van Alstyne....Kinderhook.

Growth of Foreign Varieties of Chestnuts.

W. D. Barns & Son......Middlehope.

Methods of Applying Fertilizers to Potatoes.

D. L. Downs........Baiting Hollow.
W. A. Fleet.............Cutchogue.

Soil Renovation Crops.

W. A. Fleet.............Cutchogue.
F. A. Sirrine............Riverhead.

It is seen that the foregoing list includes forty-four different experimental operations conducted on thirty-nine farms and in one cheese factory. The area of land covered by these experiments is approximately 250 acres, on 83 of which the expense of the work, whether for spraying, fertilizer tests or otherwise, is borne entirely by the Station. Such a series of observations on a commercial scale and from a business point of view can hardly fail to be profitable to New York agriculture.

Sixteen of these experimental operations, or more than one-third of the whole, have been carried on in the Second Judicial Department, in addition to which a special agent of the Station has given his time to that department alone during nearly nine months of the year. This disproportionate attention to one section of the State is justified only on the ground that a region so long under market garden cultivation is severely afflicted with

fungus and insect pests and offers specially good opportunities for experimental work.

DEPARTMENT OF ANIMAL HUSBANDRY.

The adaptability of concentrated by-products for feeding.—The question as to the source of additional protein for the ration continues to be an important one. This is particularly true in poultry feeding when large flocks are kept in confinement. Earlier experiments have shown that at times, especially during periods of rapid growth by the young, there is needed in the ration a much larger proportion of protein and of mineral matter than is supplied by the foods that must chiefly be used, as the common grains. To prevent a lack of these essential constituents various concentrated by-products are fed. The adaptability of many of these materials cannot be satisfactorily determined except by observing the effects of their use under various conditions. As contributing toward this knowledge Bulletin No. 271 reports the results from a few feeding trials in which certain by-products were freely used.

Of three highly nitrogenous rations fed to ducklings, one containing dried blood and bone meal was associated with much slower rate of growth than one containing animal meal and another, containing "milk albumen" and bone meal; though the same amount of food under each ration gave equal increase in weight. The superiority of the two rations seemed due chiefly to their greater palatability.

Of four rations carrying much concentrated food one containing a large proportion of gluten meals proved inferior, when fed to young chicks, to another having in addition bone meal, and much inferior to others in which most of the gluten meals was replaced by animal meal or a by-product called "milk albumen." Unpalatability seemed largely responsible for the inferiority of the two rations. The poorest was also deficient in mineral matter.

The rations containing "milk albumen" were more palatable and seemed more healthful than the others, but owing to the higher price for this food it was not profitably used in the desired quantity. The rations containing animal meal were more profitably fed.

The results and observations in general, like those from other trials, show a greater disadvantage in the free use of foods of uncertain palatability and healthfulness during earlier stages of growth than at any other time.

DEPARTMENT OF BACTERIOLOGY.

Quality of commercial culture for legumes.—Bulletin 270 gives the results of an extended study of the commercial bacterial cultures for inoculating legumes. These cultures had been dried upon cotton which was afterward wrapped in paper and tin foil as a preparation for shipment.

Eighteen packages of this inoculated cotton were purchased in the open market and tested at the Station laboratory. Ninety-eight tests were made, a majority of them at Geneva, but thirty-six of them were carried on by bacteriologists in other States in order to compare results with duplicate samples. The outcome of these examinations may be summed up in the statement that these cultures were worthless for practical purposes.

Further study showed that the explanation of this situation lay in the inability of *Pseudomonas radicicola,* the germ living in the nodules upon the roots of legumes, to survive when placed upon dry cotton. The worthlessness of the commercial cultures was inherent in their method of preparation.

Since the publication of this bulletin the Department of Agriculture at Washington has taken up the distribution of liquid cultures of *Pseudomonas radicicola,* and the above results which refer to the former method of distribution upon cotton, should not be understood as applying to these new cultures.

DEPARTMENT OF BOTANY.

Potato spraying experiments.—During the season of 1904 the Station made extensive potato spraying experiments. The results, taken in connection with those obtained in previous years, indicate that potato spraying may be highly profitable in this State. In fourteen farmers' business experiments, including 180 acres, the average gain due to spraying was 62¼ bushels per acre and the average net profit $24.86 per acre. Forty-one other farmers who made experiments on their own account reported an average gain of 58½ bushels per acre. In the Station ten-year

experiment at Geneva five very thorough sprayings increased the yield 233 bushels per acre while three sprayings increased it 191 bushels. In a duplicate of this experiment at Riverhead the gain due to six sprayings was 96½ bushels per acre, and to three sprayings 56½ bushels.

In one experiment soluble bordeaux was compared with soda bordeaux and with the regular lime bordeaux. Soluble bordeaux increased the yield 11 bushels per acre; soda bordeaux 51 2-3 bushels per acre; and lime bordeaux, 68 1-3 bushels per acre. The conclusion is that neither the soluble bordeaux nor the soda bordeaux is to be recommended, at least until further tests have been made.

Effect of arsenites on potato foliage.—Two arsenites were tested —paris green and arsenite of soda.

The experiments with paris green were designed to determine whether it is injurious to potato foliage when properly applied. It was used with bordeaux, with milk of lime and with water. Some rows received bordeaux only and others no treatment of any kind, the bugs being controlled by hand picking. There was no evidence that the paris green injured the foliage anywhere and the rows receiving paris green outyielded those to which no paris green had been applied. An unexpected result of the experiment was the discovery that paris green has some value as a preventive of blight. Rows treated with paris green in water yielded 46 bushels per acre more than the check rows.

The experiments with arsenite of soda indicate that if used in bordeaux it may be safely applied to potato foliage; but when used with milk of lime serious injury may result. Safety requires that it be used only in combination with bordeaux mixture.

Winter injury to fruit trees. The extremely low temperature of the winter of 1903 and 1904 together with the unfavorable weather conditions and insect and fungus epidemics of 1904, injured or killed many fruit trees in the State, especially in the Hudson River Valley.

Old trees did not withstand the cold nor recover as well as young trees. Difference of variety was usually subordinate to location, age and previous health of the trees, though in many cases there was plainly a difference in the susceptibility of varieties.

Experiments indicated that, when peach trees were less than five years old, a severe pruning or cutting back to large limbs was a successful method of treating injured trees. The same treatment for older trees was a failure. Trees that did not carry any fruit made a better recovery than those that carried even a light crop.

DEPARTMENT OF CHEMISTRY.

Some of the relations of casein and paracasein to bases and acids, and their application to cheddar cheese.—The relation of milk-casein to the cheese industry is one of fundamental importance, and the changes taking place in the processes of cheese-making and cheese-curing can be understood fully only by a careful study of milk-casein. Bulletin 261 had for its object such a study of milk-casein. Casein exists in milk as a compound with calcium, containing about 1.5 per ct. of calcium oxide (lime). When treated with acids, the lime is removed from combination with casein and free casein is formed, which is soluble in 5 per ct. salt solution and in hot 50 per ct. alcohol. When free casein is treated with acid, it forms a casein salt of the acid; casein lactate, for example, is familiar in curdled sour milk as the white solid or curd. When milk-casein is coagulated by rennet, as in cheese-making, the curd formed is calcium paracasein, which changes, in the presence of the acid formed in the cheese-making process, into free paracasein, and it is this compound that the cheese-maker aims to produce in as large amounts as possible in the cheese-curd before putting it in press. It is this free paracasein that forms the starting point of the various complex changes that take place in cheese-ripening.

The proteids of butter in relation to mottled butter.—Butter-makers are frequently troubled by the presence of white streaks and spots in butter, which do not make their appearance until the day following the packing of the butter. This trouble has commonly been attributed entirely to the uneven distribution of salt in butter. The work reported in Bulletin 263 shows that the presence of buttermilk in butter is essential to the production of mottles. The casein lactate contained in buttermilk is acted upon by salt, whether the salt is evenly distributed or not, and white masses result when buttermilk is present to too great an extent in the butter granules. It was found that mot-

tles can be prevented by removing buttermilk as fully as possible from butter-granules before salting.

Plant-food constituents used by bearing fruit trees.—The work described in Bulletin 265 was undertaken for the purpose of ascertaining the amounts of nitrogen, phosphoric acid, potash, lime and magnesia used in one growing season by well matured, bearing fruit trees. Three standard varieties were studied of each of the following kinds of trees,—apple, peach, pear, plum and quince. The fruit, leaves and new growth of wood were carefully gathered, weighed and analyzed. Peach trees used the largest amounts of plant-food per acre, after which came in their order, apple, quince, pear and plum trees. The relative amounts of the different constituents used by the different trees did not vary greatly.

DEPARTMENT OF ENTOMOLOGY.

The San José scale.—Sulphur Washes for Orchard Treatment.—The investigations of this Department for the year were largely to ascertain to what extent sulphur washes may be used in the place of the bordeaux-arsenical mixtures for orchard treatment.

As the relative abundance of orchard diseases and insects is often determined by local conditions, the experiments were distributed over a larger area than before that data regarding the fungicidal and insecticidal properties of these washes might be obtained upon as many orchard pests as possible. The orchards in which the experiments were conducted are situated on Long Island, near Riverhead; in the lower Hudson valley, near Yorktown; and in western New York at Geneva in Ontario County, near Carlton Station in Orleans County, and at Youngstown in Niagara County. The number of trees sprayed with the sulphur washes was 7,325, divided as follows: Prunes, 150; cherries, 348; plums, 1,359; peaches, 1,149; pears, 2,822, and apples, 1,497.

In most of the orchards the applications efficiently controlled the scale, but no additional data were obtained in these as to the combined fungicidal and insecticidal properties of the sulphur washes. But in Orchard IV in Ontario County results were obtained showing the effectiveness of these sprays for apple scab. One application of a sulphur wash reduced the scab by 22 per cent. A combined treatment, consisting of one application of a

sulphur wash before blossoming and two applications of a bordeaux-arsenical mixture after blossoming reduced the scab 73.7 per cent., and wormy apples (codling moth injury) 27.1 per cent., which are practically identical with the results obtained by the usual three applications of the bordeaux-arsenical mixture for the control of these two pests.

In the experiments with pear trees in Orchard II, an application of a sulphur wash before blossoming proved an efficient remedy for the pear blister mite (*Eriophyes pyri* Pyst.) Nal. Owing to the absence of pear scab no results were obtained as to the value of this treatment for this disease. For the same reason there were no data as to the effects of an early application of a sulphur wash upon brown rot.

From the results obtained in this season's work it seems safe to conclude that one application of a sulphur wash during dormant season may be safely relied on to take the place of the usual treatment with the bordeaux mixture for the control of apple scab and scale. A system of spraying that seems well adapted for the treatment of scale-infested orchards for scale, scab and codling moth is one application of a sulphur wash during dormant season, followed with the usual second and third applications of the bordeaux-arsenical mixture.

BULLETINS PUBLISHED DURING 1905.

No. 261. January.—Some of the relations of casein and paracasein to bases and acids, and their application to cheddar cheese. L. L. Van Slyke and E. B. Hart. Pages 37.

No. 262. January.—Sulphur washes for orchard treatment. II. P. J. Parrott, S. A. Beach and F. A. Sirrine. Pages 30, plates 4.

No. 263. March.—The proteids of butter in relation to mottled butter. L. L. Van Slyke and E. B. Hart. Pages 25, plate 1.

No. 264. March.—Potato spraying experiments in 1904. F. C. Stewart, H. J. Eustace and F. A. Sirrine. Pages 110, plates 16, map 1.

No. 265. I. Plant food constituents used by bearing fruit trees. II. Tabulated analyses showing amounts of plant food constituents in fruits, vegetables, etc. L. L. Van Slyke, O. M. Taylor and W. H. Andrews. Pages 26.

No. 266. April.—Report of analyses of samples of fertilizers collected by the Commissioner of Agriculture during the summer and fall of 1904. Pages 31.

No. 267. May.—Effect of certain arsenites on potato foliage. W. H. Jordan, F. C. Stewart and H. J. Eustace. Pages 22, plates 2, figure 1.

No. 268. September.—Inspection of feeding stuffs. Pages 38.

No. 269. October.—Winter injury to fruit trees. H. J. Eustace. Pages 21, plate 1.

No. 270. November.—The quality of commercial cultures for legumes. H. A. Harding and M. J. Prucha. Pages 41.

No. 271. December.—The adaptability of certain by-products as sources of protein for poultry. W. P. Wheeler. Pages 17.

No. 272. December.—Report of analyses of samples of fertilizers collected by the Commissioner of Agriculture during 1905. Page 68.

No. 273. December.—Spraying for San Jose scale. P. J. Parrott, H. E. Hodgkiss, F. A. Sirrine and E. L. Baker, Pages 28, plates 4.

No. 274. December.—Director's Report for 1905. W. H. Jordan. Pages 18.

REPORT

OF THE

Department of Animal Husbandry

W. H. JORDAN, *Director.*

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REPORT OF THE DEPARTMENT OF ANIMAL HUSBANDRY.

THE ADAPTABILITY OF CONCENTRATED BY-PRODUCTS IN POULTRY FEEDING.*

W. P. Wheeler.

SUMMARY.

Poultry require at times a much larger proportion of protein and of mineral matter in the ration than common grain foods will supply. To prevent lack of these essential constituents concentrated by-products of various kinds are fed. The adaptability of many of these materials cannot be satisfactorily determined except by observing the effects of their use under various conditions. As contributing toward this knowledge results from a few feeding trials in which concentrated by-products were freely used are here reported.

Of three highly nitrogenous rations fed to ducklings, one containing dried blood and bone-meal was associated with much slower rate of growth than one containing animal meal and another, containing "milk albumen" and bone meal; though the same amount of food under each ration gave equal increase in weight. The superiority of the two rations seemed due chiefly to their greater palatability.

Of four rations carrying much concentrated food one containing a large proportion of gluten meals proved inferior, when fed to young chicks, to another having in addition bone-meal, and much inferior to others in which most of the gluten meal was replaced by animal meal or a by-product called "milk albumen." Unpalatability seemed largely responsible for the

*A reprint of Bulletin No. 271.

inferiority of the two rations. The poorest was also deficient in mineral matter.

The rations containing "milk albumen" were more palatable and seemed more healthful than the others, but owing to the higher price for this food it was not profitably used in the desired quantity. The rations containing animal meal were more profitably fed.

The results and observations in general, like those from other trials, show a greater disadvantage in the free use of foods of uncertain palatability and healthfulness during earlier stages of growth than at any other time.

INTRODUCTION.

The question as to the source of additional protein for the ration continues to be an important one. This is particularly true in poultry feeding, when large flocks are kept in confinement. It is especially important that there shall be no lack of this essential constituent of the food at the time for rapid growth by the young.

Because the ordinary grains and coarse foods which must usually constitute the bulk of the ration do not supply a satisfactory proportion of protein various by-products are regularly fed. Several different forms of animal products are in quite common use, as well as gluten meals and other highly nitrogenous materials. Foods which differ little in protein content as ordinarily determined, or in cost, do not correspond closely in efficiency. Sometimes palatability seems to be the chief cause for difference, sometimes the condition of the food as affecting digestibility. Often the reasons for different effects are not very obvious. At times hardly perceptible taint in a food will render it unsafe for the younger chicks although it can be fed with the best of results to older fowls. The adaptability of some foods can not be very satisfactorily ascertained except by observing the effects of their use. For this reason the results of a few feeding trials not previously reported, may be of interest.

EXPERIMENT WITH DUCKLINGS.

CONDITIONS.

In one experiment three similar lots of ducklings were fed during the period of most rapid growth on rations in which 60

per ct. or more of the protein was derived from by-products of animal origin. Except a small amount of blood meal included in a grain mixture fed to each lot, these foods for Lot I consisted of "animal meal" and "meat meal," Lot II of blood meal and bone-meal, and for Lot III of "milk albumen" and bone-meal.

The "animal meal" used in one ration contained an excessive amount of bone, and bone-meal was added to the other rations to make the percentage of total ash about alike for all and to avoid any possible deficiency of mineral matter, especially of phosphate of lime. It is probable that more bone was fed than is necessary or desirable. The total ash constituents of the food represented from a little less than 14 per ct. to something over 17 per ct. of the total dry matter in the different rations. Aside from the different animal foods mentioned the rations were practically alike.

The ducklings were hatched together and were all from the same stock. Experimental feeding began when they were one week old. There were 30 birds in each lot for the first five weeks. The number was then reduced to 25 in each.

FOODS.

Besides the prepared foods mentioned, green alfalfa was fed to each lot, corn meal and a mixture, "S," composed of four parts of cream gluten meal, two parts each of pea meal and low grade flour and one part each of corn meal, wheat middlings and blood meal. To every hundred pounds of this mixture five ounces of salt was added. Sand was regularly mixed in the food.

The accompanying table shows the average composition of each food.

TABLE I.—COMPOSITION OF FOODS USED FOR DUCKLINGS.

FOOD.	Moisture.	Protein.	Ash.	Fiber.	N.-free extract.	Ether extract. (Fats.)
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Mixture "S"	13.8	31.3	1.7	1.9	49.5	1.8
Corn meal	14.6	8.1	1.4	1.9	70.4	3.6
Meat meal	7.8	62.7	4.6	(?)	7.6	17.3
Animal meal	5.8	31.4	39.8	(?)	5.7	17.3
Blood meal	11.0	85.1	3.0	(?)	.6	.3
"Milk albumen"	10.0	38.6	30.9	(?)	20.0	.5
Bone meal	5.6	19.9	64.3	(?)	4.3	5.9
Alfalfa	77.7	3.7	2.0	6.0	9.9	.7

VALUATIONS OF FOODS.

While there are continual fluctuations in the prices of feeding stuffs, the concentrated products usually cost much more than the ordinary grain foods. In estimating the cost of different rations for comparison, prices are taken that would not hold at all times, but which fairly represent the usual relative prices for the different materials. The foods used in the feeding trials reported in this bulletin were rated at the following prices: Corn meal, low grade flour and pea-meal at $22.50 per ton, wheat bran at $19, wheat middlings at $21, germ gluten meal and Atlas "gluten meal" at $25.50, Chicago gluten meal at $26, cream gluten meal at $29.50, linseed meal at $29 per ton, corn at 60 cents per bushel, wheat at 87 cents per bushel and all green fodder at $2 per ton. Meat meal, meat and bone and bone-meal were rated at $30, animal meal at $35, and blood meal at $50 per ton, "milk albumen" cost 3 cents per pound.

The records from feeding for nine weeks with the results averaged for periods of one week are shown in the accompanying tables.

TABLE II.—DUCKLINGS OF LOT I. RATION WITH ADDITIONAL PROTEIN DERIVED FROM ANIMAL MEAL AND MEAT MEAL.

Average weight at end of period.	Number of birds during period.	Average Per Fowl for Period.												Average gain in weight per fowl during period.	Dry matter in food per day for each pound live weight fed.	Cost of food for each pound net gain in weight.	Dry matter in food for each pound gain in weight.
		Mixture. S.	Corn meal.	Animal meal.	Maat meel.	Alfalfa.	Sand.	Protein in food.	Ash in food.	Fats in food.	Total food per day.	Dry matter in food per day.	Cost of food per day.				
Lbs.		*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Cts.*	*Ozs.*	*Ozs.*	*Cts.*	*Lbs.*
.3	30	1.7	1.8	1.6	.2	.7	.5	1.3	.7	.4	.9	.7	.07	2.7	2.8	2.8	1.8
.6	29	3.0	3.0	3.0	1.1	1.5	1.6	2.8	1.4	.9	1.6	1.3	.13	5.3	2.6	2.7	1.7
1.2	29	8.3	6.3	6.5	1.8	3.9	2.1	6.5	3.0	1.9	3.8	3.0	.29	9.0	3.2	3.6	2.4
2.1	29	6.5	6.9	10.2	.8	5.8	2.2	6.5	4.4	2.3	4.3	3.3	.32	13.3	2.0	2.7	1.7
2.7	29	9.6	11.5	8.0	3.4	5.8	4.7	8.8	3.8	2.6	5.5	4.3	.41	9.9	1.8	4.6	3.0
3.6	25	15.6	16.2	16.9	4.4	9.0	8.0	14.6	7.6	4.6	8.9	7.0	.68	13.5	3.1	5.6	3.6
4.3	25	13.6	13.4	11.2	3.0	9.0	3.4	11.0	5.2	3.2	7.2	5.5	.52	11.2	1.4	5.2	3.4
5.0	25	13.7	12.8	14.8	3.3	9.0	4.4	12.4	6.6	3.9	7.7	6.0	.58	10.0	1.3	6.5	4.2
5.4	25	14.6	14.7	14.4	3.6	9.0	4.9	12.9	6.5	4.0	8.0	6.3	.60	7.2	1.2	9.3	6.1

TABLE III.—DUCKLINGS OF LOT II. RATION WITH ADDITIONAL PROTEIN DERIVED FROM BLOOD MEAL AND BONE MEAL.

Average weight at end of period.	Number of birds during period.	AVERAGE PER FOWL FOR PERIOD.												Average gain in weight per fowl during period.	Dry matter in food per day for each pound live weight fed.	Cost of food for each pound net gain in weight.	Dry matter in food for each pound gain in weight.
		Mixture. S.	Corn meal.	Blood meal.	Bone meal.	Alfalfa.	Sand.	Protein in food.	Ash in food.	Fats in food.	Total food per day.	Dry matter in food per day.	Cost of food per day.				
Lbs		Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs	Cts.	Ozs.	Ozs.	Cts.	Lbs.
.3	30	1.9	1.4	.4	.6	.7	.2	1.2	.5	.1	.7	.6	.05	1.8	2.6	3.4	2.2
.5	30	2.4	2.9	1.5	1.4	1.4	1.2	2.6	1.1	.2	1.4	1.1	.12	3.5	2.7	3.9	2.1
.8	30	4.0	4.1	2.2	1.7	3.7	1.5	3.8	1.4	.4	2.2	1.6	.18	4.5	2.5	4.5	2.5
1.3	29	8.5	6.0	6.2	4.1	5.8	3.4	9.2	3.2	.7	4.4	3.3	.40	7.8	3.1	5.7	2.8
1.9	29	7.2	9.5	1.8	4.8	5.8	4.0	5.6	3.5	.8	4.2	3.1	.33	8.9	1.9	4.1	2.4
2.7	25	14.6	14.0	7.8	7.5	9.0	4.4	13.9	5.7	1.3	7.6	5.8	.67	12.2	2.4	6.1	3.3
3.2	25	8.2	9.6	4.6	4.8	9.0	3.3	8.4	3.7	.9	5.2	3.7	.41	8.1	1.2	5.7	3.2
4.0	25	12.9	13.5	5.9	5.3	9.0	4.6	11.3	4.2	1.1	6.7	5.0	.56	11.6	1.4	5.4	3.0
4.6	25	17.4	15.9	7.9	8.2	9.0	5.7	15.1	6.2	1.5	8.3	6.5	.74	9.2	1.5	9.1	4.9

TABLE IV.—DUCKLINGS OF LOT III. RATION WITH ADDITIONAL PROTEIN DERIVED FROM "MILK ALBUMEN" AND BONE MEAL.

Average weight at end of period.	Number of birds during period.	Average Per Fowl for Period.												Average gain in weight per fowl during period.	Dry matter in food per day for each pound live weight fed.	Cost of food for each pound net gain in weight.	Dry matter in food for each pound gain in weight.
		Mixture. S.	Corn meal.	Milk albumen.	Bone meal.	Alfalfa.	Sand.	Protein in food	Ash in food.	Fats in food.	Total food per day.	Dry matter in food per day.	Cost of food per day.				
Lbs.		Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Cts.	Ozs.	Ozs.	Cts.	Lbs.
.3	30	1.4	2.3	2.0	.3	.7	.1	1.5	.9	.1	1.0	.8	.10	2.7	3.0	4.0	2.0
.6	30	4.0	2.8	3.1	.7	1.4	1.8	2.8	1.6	.2	1.7	1.4	.17	4.9	2.7	3.9	2.0
1.0	30	4.2	5.5	4.7	1.3	3.7	2.2	4.0	2.5	.4	2.8	2.1	.25	6.0	2.5	4.7	2.4
1.6	30	8.4	7.6	7.9	2.0	5.6	2.6	6.9	4.1	.6	4.5	3.4	.42	10.3	2.5	4.6	2.3
2.4	30	8.3	9.3	9.2	1.9	5.6	3.9	7.5	4.4	.7	4.9	3.8	.47	11.5	1.9	4.6	2.3
3.2	25	17.0	13.3	17.9	5.2	9.0	5.7	14.7	9.5	1.2	8.9	7.0	.89	11.0	2.5	9.1	4.5
4.1	25	15.6	17.4	15.4	3.3	9.0	6.3	13.2	7.5	1.2	8.7	6.7	.83	15.0	1.9	6.2	3.2
4.6	25	11.0	11.6	10.4	3.0	9.0	4.1	9.3	5.7	.9	6.4	4.8	.58	7.6	1.1	8.5	4.4
5.3	25	15.4	15.2	15.5	3.7	9.0	4.9	13.1	7.8	1.2	8.4	6.1	.81	12.1	1.2	7.5	3.5

RATIONS.

The total food eaten per fowl during the first five weeks contained of dry matter 88.6 ounces for Lot I, 67.5 ounces for Lot II and 80 ounces for Lot III. During the next four weeks the amount was 173.4 ounces for Lot I, 146.7 ounces for Lot II and 172.5 ounces for Lot III. For the whole time Lot I took over 22 per ct. more food than Lot II and less than 4 per ct. more than Lot III.

On the average for the entire period the ash constituents represented about 14.9 per ct. of the total dry matter for Lot I, about 13.7 per ct. for Lot II and about 17.4 per ct. for Lot III. Of the total protein in the ration about 61.5 per ct. on the average for Lot I was derived from animal food, for Lot II about 62.7 per ct. and for Lot III a little over 60 per ct. The proportion for any week varied but little from the average. The ration for Lot II having the blood meal had a somewhat narrower nutritive ratio most of the time than those for the other lots. For all, however, this ratio was considerably narrower than is necessary. Under ordinary conditions wider rations would also be more economical.

RESULTS.

The average gain in weight per fowl for the nine weeks was 82.2 ounces for Lot I, 67.7 ounces for Lot II and 81 ounces for Lot III, the growth by Lot I being over 21 per ct. greater and that by Lot III nearly 20 per ct. greater than that made by Lot II. During the first five weeks considerably the fastest growth was made by Lot I and considerably the slowest by Lot II. During the next four weeks there was less difference in growth by the several lots, Lot III going a little ahead and Lot II a little behind Lot I.

The relation of increase in weight to the consumption of food was, on the average for the whole time, almost exactly alike for the three lots, one pound gain being made for every 3.1 pounds of dry matter in the food. For the first five weeks Lot I made a pound gain in weight for every 2.2 pounds of dry matter in the food, Lot II one pound for every 2.5 pounds and Lot III one pound for every 2.3 pounds. During the next four weeks for each pound gain Lot I required 4.1 pounds, Lot II 3.6 pounds and Lot III 3.8 pounds of dry matter in food.

The cost of food for each pound gain in weight during the first five weeks was about 3.4 cents for Lot I, 4.6 cents for Lot II and 4.5 cents for Lot III. For the next four weeks it was about 6.4 cents for Lot I, 6.5 cents for Lot II and 7.6 cents for Lot III. The average food cost of each pound gain in weight for the whole trial was 4.8 cents for Lot I, 5.7 cents for Lot II and 6.1 cents for Lot III.

IN CONCLUSION.

Continued feeding the same rations for a short time indicated that growth which had been retarded under the one ration was not permanently checked. While growth became slower with the maturing birds, those of Lot II made slightly the better gains. Similar results have appeared in other experiments when the inferior rations have not been radically deficient.

After the different rations had been fed for ten weeks, the birds being then 11 weeks old, and in two lots nearly full grown, the general appearance of the flocks was much in favor of Lot III. The birds were nearly all in good plumage, completely and evenly covered with feathers. Those in Lot I, though averaging somewhat heavier, showed decidedly more unevenness in plumage. Only a few were covered with feathers, the majority showing patches covered only with down and pin feathers. They were, however, in better plumage than Lot II. At ten weeks of age the average weight for Lot I was 5.4 pounds, for Lot II 4.6 pounds and for Lot III 5.3 pounds. Subsequent growth was hardly made at a profit, but during the following week the average gain per fowl was 5.6 ounces for Lot I, 6.6 ounces for Lot II and 6.2 ounces for Lot III, the food consumption being at the rate of from 7 to 9 pounds of dry matter for each pound gain.

The chief cause for the poorer results from the one ration seemed to be its somewhat inferior palatability. From 16 to 18 per ct. more food, on the average, was taken by Lots I and III. Although less food was taken by Lot II, it was used as efficiently, on the whole, as the larger quantities taken by the other lots. During the earlier stages of growth the food was used to less advantage, but for the last month of feeding even less food was required per pound gain than by Lots I and III.

The ration for Lot III was in some respects the more satisfactory and permitted practically equal growth to that by Lot I.

Owing to the higher price for the by-product called "milk albumen" the ration was less profitable, the average cost of growth exceeding by over 27 per ct. that for Lot I.

EXPERIMENT WITH CHICKS.

CONDITIONS.

At another time four similar lots of chicks were fed for two months on rations in which most of the protein was derived from highly nitrogenous by-products. For two lots there was added to the basal ration animal food. Except for a little bone meal fed to one lot the two others had no food of animal origin. The added food supplied from about one-quarter to one-third of the total dry matter of the ration and about half of the total protein. The experimental feeding began when the chicks were two weeks old.

FOODS AND RATIONS.

Each lot was fed cracked corn, wheat, green alfalfa and two ground grain mixtures. One mixture, "T," consisted of two parts by weight of corn meal and one part each of wheat bran and wheat middlings. Another mixture, "V," consisted of four parts corn meal, three parts each of wheat middlings, Chicago gluten meal, germ gluten meal and Atlas "gluten meal" and two parts each of O. P. linseed meal and wheat bran. Besides these foods Lot IV, was fed animal meal, Lot V, "milk albumen" (a by-product from milk sugar factories), Lot VI, Chicago gluten meal and later cream gluten meal, and Lot VII ground bone with either Chicago gluten meal or cream gluten meal. The accompanying table shows the average composition of each food.

TABLE V.—COMPOSITION OF FOODS USED FOR CHICKS.

FOOD.	Moisture.	Protein.	Ash.	Fiber.	N.-free extract.	Ether extract. (Fat.)
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Mixture "V"	12.9	23.8	2.8	5.7	48.8	6.0
Mixture "T"	15.7	12.0	2.9	4.9	60.8	3.7
Corn meal	15.5	7.9	1.4	5.4	66.7	3.1
Chicago gluten meal	11.0	36.5	.9	2.2	47.1	2.3
Cream gluten meal	10.6	42.7	1.0	1.0	43.9	.8
"Milk albumen"	7.6	52.7	23.6	(?)	14.0	2.1
Meat meal	9.4	62.1	3.8	(?)	9.3	15.4
Animal meal	6.4	37.6	42.8	(?)	4.5	8.7
Blood meal	11.2	81.3	3.1	(?)	4.1	.3
Bone meal	5.6	19.9	64.3	(?)	4.3	5.9
Alfalfa	79.6	4.0	1.8	5.3	8.8	.5

The proportion of the total dry matter of the ration supplied by the various added foods was on the average about 26 per ct. for Lots IV and V, about 24 per ct. for Lot VI, and about 34 per ct. for Lot VII. The large proportion in the case of Lot VII, was due to the addition of bone meal with the gluten meals to avoid any deficiency of phosphate of lime, such as presumably existed in the ration for Lot VI. The proportion of the total dry matter represented by all the ash constituents was on the average for Lot IV 14 per ct., for Lot V 8.8 per ct., for Lot VI 2.8 per ct., and for Lot VII 6.4 per ct. During the first four weeks of feeding this percentage was slightly lower than the average with each lot. The proportion of the total protein derived from the added food was about 44 per ct. for Lot IV, over 52 per ct. for Lot V, about 46 per ct. for Lot VI, and 54 per ct. for Lot VII. There would have been less variation in this respect had the foods used corresponded more closely with preliminary samples. The nutritive ratio varied somewhat at different times with each lot from about 1:2.3 to 1:3.5, being most of the time considerably narrower than is necessary.

RESULTS.

The condensed records of feeding and the results averaged for periods of two weeks are given in the accompanying tables.

TABLE VI.—CHICKS OF LOT IV. RATION WITH ADDED PROTEIN DERIVED FROM ANIMAL MEAL.

Average weight at end of period.	Average number of chicks during period.	Average Per Fowl for Period.												Average gain in weight per fowl during period.	Dry matter in food per day for each pound live weight fed.	Cost of food for each pound net gain in weight.	Dry matter in food for each pound growth made.
		Mixture. V.	Mixture T.	Corn.	Wheat.	Animal meal.	Alfalfa.	Protein in food.	Ash in food.	Fats in food.	Total food per day.	Dry matter in food per day.	Cost of food per day.				
Lbs.		Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Cts.	Ozs.	Ozs.	Cts.	Lbs.
.3	43	2.3	1.3	.9	1.5	1.9	1.0	1.7	.9	.4	.6	.5	.05	2.9	2.2	4.6	2.4
.6	41	3.2	3.1	1.8	2.7	3.6	2.4	3.0	1.8	.7	1.2	.9	.09	4.2	2.0	4.6	3.1
.8	41	4.7	4.0	2.2	3.5	5.0	2.7	4.1	2.5	1.0	1.6	1.2	.12	3.2	1.8	8.5	5.5
1.0	38	5.7	3.6	3.0	4.3	5.4	4.4	4.7	2.8	1.1	1.9	1.4	.13	2.7	1.6	15.5	7.6

CHICKS OF LOT V. RATION WITH ADDED PROTEIN DERIVED FROM "MILK ALBUMEN."

Average weight at end of period.	Average number of chicks during period.	Average Per Fowl for Period.												Average gain in weight per fowl during period.	Dry matter in food per day for each pound live weight fed.	Cost of food for each pound net gain in weight.	Dry matter in food for each pound growth made.
		Mixture V.	Mixture T.	Corn.	Wheat.	Milk Albumen	Alfalfa.	Protein in food.	Ash in food.	Fats in food.	Total food per day.	Dry matter in food per day.	Cost of food per day.				
Lbs.		Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Cts	Ozs.	Ozs.	Cts.	Lbs.
.3	50	1.9	1.3	.7	1.3	1.8	.8	1.8	.5	.2	.6	.5	.05	2.2	2.1	5.4	2.8
.5	49	2.9	2.3	1.5	2.2	2.8	2.0	2.9	.9	.4	1.0	.8	.09	2.8	1.9	7.2	3.8
.8	48	4.4	3.3	2.0	3.0	4.6	2.3	4.5	1.4	.6	1.4	1.1	.13	4.5	1.8	6.7	3.5
.9	46	6.4	3.1	3.3	4.7	5.8	3.6	5.9	1.8	.8	1.9	1.5	.17	1.9	1.8	22.1	10.9

Table VII.—Chicks of Lot VI. Ration with Added Protein Derived from Gluten Meal.

Average wt. at end of period.	Average No. chicks during period.	Average per Fowl for Period.													Average gain in weight per fowl during period.	Dry matter in food per day for each pound live weight fed.	Cost of food for each pound net gain in weight.	Dry matter in food for each pound growth made.
		Mixture V.	Mixture T.	Corn.	Wheat.	Chicago gluten meal.		Alfalfa.	Protein in food.	Ash in food.	Fats in food.	Total food per day.	Dry matter in food per day.	Cost of food per day.				
Lbs.		Ozs.	Ozs.	Ozs.	Ozs.	Ozs.		Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Cts.	Ozs.	Ozs.	Cts.	Lbs.
.2	48	1.3	1.0	.7	1.0	1.3		.9	1.1	.1	.2	.4	.3	.03	.9	1.9	15.0	5.3
.3	41	1.7	1.5	1.0	1.5	1.6		2.4	1.5	.2	.3	.7	.5	.04	1.0	1.9	11.4	6.6
						cream gluten.												
.4	36	2.2	1.2	1.1	1.6	2.2		3.1	1.9	.2	.3	.8	.6	.05	1.0	1.7	29.7	7.7
.5	33	3.8	3.0	1.4	2.2	3.4		5.1	3.1	.4	.5	1.4	.9	.08	1.6	2.1	12.5	7.9

Chicks of Lot VII. Ration with Added Protein Derived from Gluten Meal and Bone Meal.

		Average per Fowl for Period.																
						Chicago gluten meal.	Bone meal.											
						Ozs.	Ozs.											
.2	46	1.4	1.0	.7	1.0	1.7	.3	.8	1.4	.3	.2	.5	.4	.04	1.5	2.0	7.4	3.8
.4	41	1.8	1.5	.8	1.4	2.1	.4	2.0	1.7	.4	.3	.7	.5	.05	2.0	1.7	5.6	3.7
						Cream gluten.												
.5	38	2.5	1.3	1.2	1.4	3.0	.6	2.3	2.5	.6	.3	.9	.6	.06	2.4	1.5	5.4	3.8
.7	37	3.8	2.9	1.6	2.3	5.0	1.0	3.6	4.1	1.0	.5	1.4	1.1	.10	3.2	1.7	7.0	4.8

Most of the chicks were Leghorns. In general, growth was slow. The average gain in weight made per chick was 12.9 ounces for Lot IV, 11.5 ounces for Lot V, 4.6 ounces for Lot VI and 9.0 ounces for Lot VII. During the first four weeks the average gains were respectively 7.1 ounces, 5.0 ounces, 1.9 ounces and 3.5 ounces. The dry matter in the food consumed for each pound gain in weight was on the average 4.4 pounds for Lot IV, 4.6 pounds for Lot V, 6.9 pounds for Lot VI and 4.1 pounds for Lot VII. During the first four weeks the ratio was 2.8 pounds for Lot IV, 3.3 pounds for Lot V, 6.0 pounds for Lot VI, and 3.7 pounds for Lot VII.

The cost of food for each pound gain in weight was 7.4 cents for Lot IV, 9.0 cents for Lot V, 14.6 cents for Lot VI and 6.4 cents for Lot VII. During the first four weeks these costs were 4.6 cents, 6.4 cents, 12.8 cents and 6.3 cents for each respectively. Allowance is made for any loss caused by accident obviously uninfluenced by feeding. The weight of any chick that died was accounted as loss in weight when estimating the food cost of growth made.

COMMENTS.

An unusually large number of chicks died during the experiment and a few were taken by crows. Although each lot contained chicks of five breeds and crosses, over 90 per ct. of those that died during the first two weeks, when most of the loss occurred, were of one breed (W. Wyandottes). This with other considerations, seemed to indicate that the excessive mortality was due chiefly to low vitality in certain stock and not so much to radical defects in all the rations. On the other hand some lack of vigor in the stock might more plainly evidence the relative healthfulness of different foods, although their absolute capabilities might not be fully shown.

When the death of weaker chicks seems caused or hastened by an unusual ration the final net result is the better indication of its value, but when loss occurs through accident obviously unrelated to the food, average individual results for the different periods are the better guide. The general appearance of health and vigor, or the opposite, counts for much with the feeder though not always plainly indicated by the ordinary data collected.

In earlier experiments it was always found difficult, except by feeding unusual materials, to compound a ration solely of vegetable origin that would be as palatable and efficient as one containing animal foods. In this case the less costly ration for Lot VI containing no animal food, and also supposedly lacking in mineral matter, gave much the poorer results. Growth was exceedingly slow and more food was required for the little made. Owing to excessive mortality among the chicks the net cost of production was high and unprofitable.

With small lots of chicks inferiority in average rate of growth, as age increases, under one ration as compared with another may sometimes be due to a much smaller proportion of males. No disadvantage to Lot VI came from this factor, for 56 per ct. of the chicks proved to be males in Lot VI, while in the other three lots the percentage ran from 41 to 42.

Lot VII having the same foods as Lot VI with addition of some bone meal made a better showing, but one in general inferior to that for either Lot IV or V. While somewhat less food, on the average, was required per pound gain and at a lower cost than for any other lot, growth was very slow. About 28 per ct. faster growth was made by Lot V and 43 per ct. faster by Lot IV. The unpalatability of the ration for Lot VII seemed chiefly responsible for its inferiority to the two others, for the relation of product to food with the smaller consumption was as good on the average as for other lots. The ration for Lot VI suffered on this account though inferior in other ways. Flavoring the gluten meals with oil of anise and fenugreek did not lead to much greater consumption. "Cream gluten meal" was more readily eaten than "Chicago gluten meal" and was fed during the latter half of the trial. None of the concentrated by-products mentioned was fed separately but always mixed with some standard food or foods.

The by-product called "milk albumen" was palatable and somewhat superior in this respect to the animal meal. It also seemed the more healthful food; but the chicks that remained in health under the animal meal ration made the faster growth. The "milk albumen" fed at this time was of much higher grade than was obtained later for feeding ducklings (see tables I and

V). Because of the higher price for the food, growth under the ration containing the "milk albumen" was the more costly.

The observations and results, on the whole, as have those of other feeding trials, indicated the disadvantage of freely using foods of uncertain palatability and healthfulness during earlier stages of growth more than at any other time.

REPORT

OF THE

Department of Bacteriology.

H. A. Harding, *Dairy Bacteriologist.*

M. J. Prucha, *Assistant Bacteriologist.*

TABLE OF CONTENTS.

REPORT OF THE DEPARTMENT OF BACTERIOLOGY.

THE QUALITY OF COMMERCIAL CULTURES FOR LEGUMES.*

H. A. Harding and M. J. Prucha.

SUMMARY.

I. During the past two years much interest has been shown in the inoculation of legumes with bacteria to enable the legumes to obtain nitrogen from the air.

II. These bacteria have been distributed in a dried condition upon cotton. Before being applied to the seeds the cotton is put into a solution of chemicals and the bacteria allowed to multiply.

III. These packages of treated cotton have had a wide sale at a high price—two dollars for a package sufficient to treat an acre—while the cost of production was less than ten cents.

IV. This bulletin gives the results of a bacteriological examination of 18 such packages of cotton.

V. These examinations made it very evident that the packages were worthless for practical purposes.

VI. Substantially identical results upon six of these packages were obtained in five separate laboratories.

VII. It was shown that the failure of these cultures was inherent in the method of their preparation rather than in any knavery of their producers.

VIII. While these results will explain the many failures from the use of cotton cultures they should not be understood as being opposed to the idea of treating the seed of legumes with living bacteria.

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*A reprint of Bulletin No. 270.

INTRODUCTION.

The idea of using bacterial cultures for inoculating legumes in order to fix nitrogen from the air is an old one. It was quite prominently before the public about 10 years ago[1] but became discredited because the cultures were not found to be effective.

During the past two years this idea has again been brought to public notice[2] through the announcement that the Department of Agriculture at Washington had solved the problem of preparing active cultures in convenient form for distribution. The new method (see Letters Patent, page 51) consists in growing *Pseudomonas radicicola* (Byerinck) Moore, the germ necessary to the fixation of nitrogen, in a solution poor in nitrogen, and then transferring this growth to absorbent cotton. When dried this cotton can be sent through the mail. On receipt by the farmer, the cotton is dropped into a solution prepared from chemicals and clean water. After developing for two or three days this solution is applied to the seed. For the season of 1904, the Department sent out large numbers of cultures. Some of the results from their use are given in a bulletin[3] which was issued Jan. 23, 1905, and distributed early in February.

Interest in the subject grew so rapidly that by February 27 all the cotton cultures which the Department would be able to supply to farmers before July 1[4] had been promised. This made it necessary for a large number of interested farmers either to omit the use of cultures or to purchase the material in the open market.

During the past winter and spring, inquiries were constantly coming to the Station from farmers regarding commercial cultures for inoculating legumes. Many of these inquirers asked specifically concerning the purity and quality of the commercial cotton cultures. As this was the first season these firms had been doing business, we lacked data from which to answer these questions. This bulletin gives the results of an attempt to secure such data.

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[1]Goessman, C. A. Experiments with "Nitragin." Hatch Exp. Station, Report, 9:177-189. 1897.

[2]Grosvenor, G. H. Inoculating the soil. A remarkable discovery in scientific agriculture. Century Magazine, page 831. October, 1904.

[3]Moore, G. T. Soil Inoculation for Legumes. Bul. 71, Bureau of Plant Industry, U. S. Dept. Agr.

[4]See circular, page 50.

Notwithstanding the active demand for this material, there have been, so far as we can learn, but two firms preparing the commercial cultures during the present season. The Vermont Seed and Soil Inoculation Co., Burlington, Vt., has sold a small amount of cotton in this State but we have not been able to obtain any of their product through commercial channels. The National Nitro-Culture Co., West Chester, Pa., began to advertise as early as November of last year, and has practically had a monopoly of the commercial end of the business during the past season. Our orders, placed with the large seedsmen of the country, have all beeen filled with these goods. As theirs were the only goods that we could find in the open market, a discussion of the commercial cultures is necessarily restricted to their output.

ACKNOWLEDGMENTS.

In addition to the courtesies extended by the Vermont Soil and Seed Inoculation Co., the National Nitro-Culture Co., and the Bureau of Plant Industry, we are indebted to a number of others. Mr. J. B. Anderson kindly purchased samples for us in the open market. Prof. J. L. Stone aided us, both by sugtions and by supplying a considerable amount of cotton cultures from various sources. Prof. F. D. Chester, Dr. J. G. Lipman, Dr. E. M. Houghton and Dr. C. E. Marshall contributed to the accuracy of the work, both by suggestions as to laboratory methods, and by carrying out a system of check determinations upon duplicate samples of cotton. Johnson & Johnson kindly furnished us with some specially high grade cotton for certain tests. Our colleague, Mr. E. B. Hart, has been helpful with suggestions and assistance in the chemical questions which have arisen.

OUTLINE OF INVESTIGATION.

METHOD OF ATTACKING THE PROBLEM.

Since the cotton was supposed to contain a practically pure culture of *Pseudomonas radicicola,* it seemed that an examination in the laboratory might determine that this organism was present in proper quantity. It should be remembered, however, that much stress has been laid upon the previous training which the

germs have undergone.[5] It is conceivable that the proper organism might be present in large numbers and still be of little value in bringing about the desired fixation of nitrogen in connection with legumes. Accordingly it was our purpose first to study the commercial cotton, and later to test the *Ps. radicicola* found there upon legumes as time and opportunity would permit.

APPLICATION TO DEPARTMENT FOR CULTURES AND METHODS.

To make the test upon legumes fair, it was necessary that germs from the cotton should be so handled during the interval between their isolation and the test as not to decrease their ability to fix nitrogen. Since the Department of Agriculture at Washington had improved the previous methods of cultivating *Ps. radicicola* so as to accomplish this end, we naturally turned to them for information.

In determining the identity of a new culture in the laboratory, it is of great assistance to have an authentic culture for direct comparison with the suspected organism. Accordingly, we included in our application a request for an authentic culture of *Ps. radicicola*. The following correspondence is self-explanatory:

GENEVA, N. Y., *March* 18, 1905.

MR. GEORGE T. MOORE,
Bureau of Plant Industry,
Washington, D. C.

DEAR SIR :—As you are probably well aware, recent publications have created a marked interest on the part of the agricultural public, in the subject of soil inoculation. Requests for information and for cultures are coming to the Station daily. In the past we have referred those interested in the subject to your Department with the suggestion that they might be furnished with sufficient cultures to test the matter on their own land. Prof. Stone of Ithaca recently informed me that you had suspended distribution of such material. Under the present circumstances it seems that the people must either drop the matter or purchase material of a commercial firm at what seems an exorbitant price.

[5] Summary of Bul. 71, Bureau of Plant Industry, U. S. Dept. Agr.

There are many questions in connection with the use of cultures which await solution, and in the present situation, it seems as though the Station was practically forced to take the matter up. Dr. Jordan requests me to inquire whether you are willing to furnish us with various stock cultures and other information which will assist us in starting this work?

Yours truly,
H. A. HARDING,
Bacteriologist.

WASHINGTON, D. C., *March* 23, 1905.

PROF. H. A. HARDING,
Bacteriologist, N. Y. Agricultural Experiment Station, Geneva, N. Y.:

DEAR SIR:—Your letter of March 18, to Dr. George T. Moore is received. In reply to your inquiry regarding the putting up of inoculating material for legumes, I would say that we shall be very glad indeed to furnish you with all the information necessary. For various reasons it seems better for those who are undertaking work of this kind to prepare their own stock cultures, but if this cannot be done we are willing to furnish all the cultures necessary. It is not strictly correct to say that we have suspended the distribution of the inoculating material. While it is true that our supply for spring sowing is practically exhausted, we having promised all that it will be possible for us to furnish between now and the first of July, it is not our intention to discontinue sending out the material, and it is probable that in the future our facilities will be sufficiently increased to supply all reasonable demand. Prof. Stone in his statement probably refers to the circular, a copy of which is enclosed herewith, which we have been sending in reply to all applications recently received. If you desire specific information regarding the method developed by us for the cultivation and distribution of the nodule-forming bacteria, kindly let me know and I shall be glad to furnish it.

Yours very truly,
A. F. WOODS,
Chief Pathologist and Physiologist.

CIRCULAR.

DEAR SIR:—Your letter of recent date in regard to securing nitrogen-fixing bacteria has been received.

We greatly regret that our supply of packages prepared for inoculating the legume (or legumes) which you mention is completely exhausted. We shall not be able to furnish any greater quantity than has already been promised for spring sowing. A limited quantity for use with fall-sown leguminous crops will, however, be available, application for which should be made after July 1, 1905.

When applying for inoculating material, do not neglect to state the probable time for planting, kind of seed, and quantity to be treated, so that we may send you the organisms in the best possible condition. This is necessary, as our methods require the inoculation to be made either before or at the time of planting the seed. Full directions for use are included in each package sent out.

The bacteria are beneficial only in connection with legumes (including the clovers, vetches, peas, beans, etc.,) and are not applicable to other farm or garden crops. Even with legumes these bacteria are of no decided benefit except when the proper nodule-forming organisms are lacking in the soil, but a crop of nodule-bearing legumes improves the soil for succeeding crops.

In replying please refer to this circular.

Yours very truly,

A. F. WOODS,

Chief Pathologist and Physiologist.

Approved:

B. T. GALLOWAY,

Chief of Bureau.

GENEVA, N. Y., *March* 25, 1905.

DR. A. F. WOODS,

Department of Agriculture, Washington, D. C.

MY DEAR SIR:—Yours of March 23, is received. We will be very much obliged if you can send us a culture of the organism for alfalfa and full directions for propagating and preparing the same for distribution. If our other work will permit we will desire to obtain other cultures later.

Yours truly,

H. A. HARDING,

Bacteriologist.

WASHINGTON, D. C., *March* 29, 1905.

PROF. H. A. HARDING,

Bacteriologist, N. Y. Agricultural Experiment Station, Geneva, N. Y.:

DEAR SIR:—In reply to your letter of March 25, I would say that upon investigation I find we do not have on hand at the present time any pure cultures of the organism for alfalfa. We do not attempt at this time of the year to keep cultures in stock, as we depend upon getting fresh ones from the roots of alfalfa plants, and we have enough cotton prepared to supply the demand for cultures to be sent out before the first of July. However, I am sure you will have no difficulty in getting pure cultures for yourself if you follow the directions given in the specifications to letters patent No. 755,519 issued March 22, 1904. A copy of the patent can be obtained by writing to the Commissioner of Patents, Washington, D. C., and enclosing five cents in currency. In case there is any further information I can give you after the receipt of the formulas contained in the patent specifications, do not hesitate to call upon me.

Yours very truly,

A. F. WOODS,

Chief Pathologist and Physiologist.

A copy of letters patent No. 755,519 was received April 8, 1905.

UNITED STATES PATENT OFFICE.

GEORGE T. MOORE, OF WASHINGTON, DISTRICT OF COLUMBIA.

PROCESS OF PREPARING FOR DISTRIBUTION ORGANISMS WHICH FIX ATMOSPHERIC NITROGEN.

Specification forming part of Letters Patent No. 755,519, dated March 22, 1904.

Application filed May 4, 1903. Serial No. 155,695.
(No specimens.)

To all whom it may concern:

Be it known that I, GEORGE T. MOORE, a citizen of the United States, residing at Washington, in the District of Columbia, have invented new and useful improvements in the process of prepar-

ing for distribution organisms which fix or gather atmospheric nitrogen, of which the following is a specification:

This application is made under the act of March 3, 1883, chapter 143, and the invention herein described and claimed, if patented, may be used by the government of the United States or any of its officers or employees in prosecution of work for the government or by any other person in the United States without the payment to me of any royalty thereon.

The invention relates to the process of growing these organisms and preparing them for distribution.

The invention has for its object the production of more highly effective organisms and their distribution in a form preventing deterioration and easily applied in agriculture. All work that has heretofore been done in the cultivation of nitrogen-gathering root-tubercle organisms for use in agriculture has been done in culture media containing either decoctions of the leguminous plants, from which these specific organisms in each case were obtained or in media containing some other available form of combined nitrogen not free or atmospheric. When there is available combined nitrogen in the medium, the organisms instead of depending solely upon the atmospheric nitrogen for their nitrogen-supply draw upon the nitrogenous materials of the culture medium—such, for example, as proteids, nitrates, ammonium compounds, etc.—for which reason they do not develop their full nitrogen-gathering power and rapidly deteriorate.

By my process the organisms are first obtained from the tubercles or swellings on the roots of the leguminous plants—such as clovers, cow-peas, beans, etc. After the tubercles are thoroughly washed and surface sterilized in the ordinary ways the interior of the tubercle is cut out under sterile conditions and mixed in a medium consisting of water containing about one per ct. commercial agar-agar, about one per cent. maltose sugar or cane-sugar, (the former being the better,) about .02 to .05 per ct. magnesium sulfate, and about 0.1 per ct. monobasic potassium phosphate. This solution is made up in the ordinary way and sterilized according to ordinary bacteriological processes. It differs from ordinary culture media for bacteria only in the absence of a source of combined nitrogen. The agar may be varied above or below the amount suggested. The maltose or

cane-sugar may be increased to ten per cent., the magnesium sulfate to one per cent., the monobasic potassium phosphate to two per cent., or the amounts may be lowered below the quantities first mentioned. In the latter case, however, the food materials are more quickly used up. The organism multiplies as long as the materials in solution are not exhausted. Other compounds may be used as sources of magnesium, potassium, and phosphoric acid. Although I usually leave nitrogen out of the culture medium at this stage, its absence is not essential, as the object of the first step is simply to separate the organisms into pure cultures free from mold or other contamination, the process of separating out in this fashion being familiar to all bacteriologists and in common use. They grow best between 20° and 30° centigrade, and light or its absence is immaterial. When pure cultures are thus obtained, the organism is transferred immediately, or after several weeks, if desired, by any of the bacteriological transfer methods in use to water containing about one per cent. cane-sugar or maltose, (the latter being the better,) about .02 to .05 per ct. magnesium sulfate, and about 0.1 per ct. monobasic potassium phosphate, or equivalent sources of magnesium, potassium, and phosphorus, as in the case of the first-described medium. The quantities used may here also vary, as stated above; but the per cents. given have been found to be the most favorable for growth under ordinary conditions. One cubic centimeter of the culture will suffice for impregnating one hundred liters of the fluid. Any kind of container or vessel that can be easily cleaned will serve for this purpose; but Erlenmeyer flasks are best where small quantities are to be cultivated under antiseptic conditions. In this solution, which should be kept between 20° and 30° centigrade, in light or in darkness, as desired, the organisms increase very rapidy and have to obtain all of their nitrogen in the free state from the atmosphere or from the atmospheric nitrogen in solution in the medium. This liquid culture solution, even when in large quantity, will in a few days become milky in appearance by the presence of immense numbers of the developing organisms. The water containing the organisms, where direct use is desired, is then sprinkled upon seeds or soil; but for the purposes of preservation and distribution the following steps are taken: Absorbent cotton or other equivalent material is dipped

into the water containing the organisms or the water containing the organisms is sprinkled upon the cotton or other material and the same thoroughly air-dried in a chamber free from dust or contamination by molds. The drying is facilitated by forcing a current of air through the chamber by aspiration through sulfuric acid, potassium hydroxid, calcium hydroxid, sodium hydroxid, or any of the other ordinary materials used in laboratories for drying. In this dry form the organisms may be kept indefinitely without deterioration or change and may be safely, easily, and cheaply transported to any distance, either through the mails or otherwise. In using the organisms preserved as above described the dry absorbent material containing them is simply dropped into a water solution of the same composition as above described. Where the purpose is to treat soil or seed, it is not necessary to observe strictly antiseptic precautions. Ordinary clean vessels or tubs may be used, simply protected from dust, and ordinary wellwater or rainwater is used in making the culture solution, as the amount of nitrates or ammonia which such waters ordinarily contain does not interfere with the vitality of the organisms at this stage of the process. The temperature and light conditions should be as previously stated. In from twelve to forty-eight hours the organisms will have increased in the water culture as in the first instance. At this stage in order to stimulate a very rapid division of the bacteria about one per cent. phosphate of ammonia is added to the culture solution. The quantity of liquid culture that may thus be obtained is limited only by the amount of water used containing the sugar, magnesium sulfate, and potassium phosphate or other equivalent sources of magnesium, potassium, and phosphorus, as above described. After thus obtaining the liquid culture it is then necessary only to sprinkle the seeds or soil to be treated with water containing the organisms or to dip the seeds into water containing the organisms and then dry them in the ordinary way to facilitate planting. The propagation of the bacteria should not be continued longer than twelve to forty-eight hours after the addition of the phosphate of ammonia; otherwise they will deteriorate in nitrogen-fixing power, as previously explained, and organisms thus stimulated should be used only for seed or soil impregnation and not for preservation or distribution.

Having thus described my invention, what I claim, and desire to secure by Letters Patent, is—

The process of preparing for distribution nitrogen-gathering organisms, which consists in moistening suitable absorbent material with a solution in which such organisms are suspended, and afterward thoroughly drying the said materials substantially as hereinbefore described.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

GEORGE T. MOORE.

Witnesses:

A. F. WOODS,

GEO. P. MCCABE.

MEDIA USED IN THE INVESTIGATION.

The Letters Patent of Dr. Moore gives a clear statement of the media required in developing cultures of *Ps. radicicola.* Concerning the water and the ammonium phosphate to be used, the directions might have been more specific.

While the water is not designated as "distilled," that is the kind commonly used in making bacteriological media. Moreover, the reference to "ordinary wellwater or rainwater" toward the close of the paper, evidently precludes the idea of their being used in the laboratory work. It has accordingly been taken for granted that distilled water was what was intended.

"Phosphate of ammonia" does not indicate which of the three possible forms is to be used. This point was referred to Dr. Moore, who replied as follows:

WASHINGTON, D. C., *July* 27, 1905.

PROF. H. A. HARDING,

Bacteriologist, N. Y. Agricultural Ex. Station,

Geneva, N. Y.

DEAR SIR:—Your letter of July 14 was awaiting me upon my return to Washington, and I hasten to reply.

We have experimented with all of the ammonium phosphates and while the mono-basic seem to be a little the best, we have used the di-basic almost entirely because of its cheapness.

Our experience with the tri-basic salt was that the solution produced was too alkaline, and it did not seem to be quite so soluble. This may have been due to the particular grade we had at the

time, but for all practical purposes I think the di-basic is the best to use.

I am very truly yours,

GEORGE T. MOORE,

Physiologist and Algologist.

While the formulæ of Dr. Moore have been most used, other combinations have been employed. For the sake of brevity and exactness these combinations are given below, accompanied by a laboratory number which has been found useful in our records. In this media record the digits signify the form of media, as bouillon, gelatin, or agar; the first decimal place gives the kind of sugar employed and the second decimal place is left for any other variation. Thus, 1.31 and 3.31 signify the Washington formula for bouillon and agar respectively.

MEDIA USED IN INVESTIGATION.

Laboratory number of media.	COMPOSITION OF THE MEDIA.	Reaction.
1.00	5 gr. Beef extract—Liebig's 5 gr. NaCl 10 gr. Witte's peptone 1000 gr. Distilled water	1.5 per cent normal acid to phenolthaline
1.31	1 gr. Potassium phosphate monobasic 0.5 gr. Magnesium sulphate 10 gr. Cane sugar 1000 gr. Distilled water	Reaction not adjusted
1.32	Same as above, using tap water	Reaction not adjusted
1.33	Same as above, using well water	Reaction not adjusted
1.34	Same as above, using rain water from a cistern	Reaction not adjusted
3.20	5 gr. Beef extract—Liebig's 5 gr. NaCl 10 gr. Peptone—Witte's 1000 gr. Distilled water 15 gr. Agar 10 gr. Lactose	1.5 per cent normal acid to phenolthaline
3.31	1 gr. Potassium Phosphate—monobasic 0.5 gr. Magnesium sulphate 10 gr. Cane sugar 10 gr. Agar 1000 gr. Distilled water	No adjustment in reaction
3.32	Same as above, using tap water	No adjustment in reaction
3.34	Same as above, using rain water from a cistern	No adjustment in reaction

SEARCH FOR PS. RADICICOLA ON DEPARTMENT COTTON.

Having failed to secure an authentic culture of *Ps. radicicola*, but having the directions for properly isolating the culture, recourse was had to the cotton sent out from the Department at Washington as the most reliable source for obtaining the desired organism.

April 18, Prof. Stone kindly placed at our disposal a package which he had received from Washington approximately two weeks previous to that date. It was stamped "Alfalfa. Culture No. 256." The cotton in this package was wrapped in layers of paper and this in tinfoil. The package was sealed by the label which was intact at the time we received it.

At each examination the package was carefully opened under conditions which would offer the smallest practical opportunity for contamination. After removing the desired sample of cotton with sterile instruments, the remainder was carefully returned to the package. This and all the other packages were held in our stock culture room at approximately 17° C. (65° F.) when not being used in the laboratory.

First attempt.—We assumed that *Ps. radicicola* was present on the cotton in immense numbers. In such a case a short soaking in water would loosen quantities of them so that they might be recovered by plate methods.

On April 12, a portion of the cotton, the size of a small test tube plug, was placed in sterile water for two hours and repeatedly shaken. An ordinary platinum loop of this water was then plated in (3.20 and 3.31) agar. On April 22, no growth had appeared on any of the plates except a few molds and a few chromogenic bacteria, evidently not *Ps. radicicola.*

Second attempt.—By April 17, it had become evident that no satisfactory growth was appearing on the first set of plates. The sample of cotton had now been five days in the sterile water with no evidence of growth. Thinking that food material might induce some development, 5 cc. of (1.00) bouillon was now added. Two days later plates were made as before, using (3.20 and 3.31) agar. At this time there was a slight turbidity in the fluid surrounding the cotton and a hanging drop examination under the microscope showed germ life to be fairly

abundant. April 22, the plates of both kinds of agar contained abundant but miscellaneous growth. No colonies resembled *Ps. radicicola.*

Third attempt.—On April 17, a portion of the Department cotton, the size of a walnut, was placed in a sterile flask containing 40 cc. of sterile distilled water and 5cc. of melted (3.31) agar. On the following day plates were made with (3.31) agar and quantities of fluid from the flask ranging from a drop to 1 cc. On April 27, no colonies had appeared on the plates which had received 1 cc. and ½ cc. respectively, and in the entire series only an occasional colony appeared on a few of the plates. These colonies did not resemble *Ps. radicicola.*

Fourth attempt.—The authentic culture of *Ps. radicicola* which we desired before attacking the main problem had now been received from Washington (see p. 62), but our repeated failures seemed to justify another examination of the Department cotton. This time the cotton culture was allowed to develop in the nutrient solution which was said to be favorable to the desired germ but unfavorable to the growth of other forms.[6]

On April 24, a piece of the Department cotton the size of a test tube plug was placed in a sterile flask containing 250 cc. (1.31) bouillon. By April 27 the mixture was decidedly turbid and an examination in hanging drop showed an abundant growth of yeasts. On April 29 plates were made with (3.20 and 3.31) agar, inoculating with one loop from the flask and making a transfer from this tube to two other tubes. May 5 there was an abundant growth on all of the plates. A few of the colonies were yellow. The remainder were chalky though somewhat transparent and might be mistaken for *Ps. radicicola.* Microscopic examination showed these colonies to be yeasts.

CONTROL OF THE MEDIA.

Such repeated failures would have cast suspicion upon the quality of our media but for some accompanying observations. On April 12 and 19 cultures were made in considerable numbers from nodules on alfalfa plants. On each of these days we used for this purpose portions of the same media which were used on

[6]Moore, G. T., and Robinson, T. R. U. S. Dept. of Agr., Farmer's Bul. No. 214, p. 16, 1905.

these days in the examination of the Department cotton. The plates inoculated from the nodules and from the cotton solutions were grown side by side. While the plates representing the cotton solutions failed, all but one of the plates inoculated from the nodules developed colonies which closely resembled the description of *Ps. radicicola.* Transfers from these colonies were later compared with the authentic cultures from Washington and are thought to be identical. In many of the plates from the nodules the growth of *Ps. radicicola* was both abundant and practically pure.

Exception may be taken that inoculating from the nodule introduced a trace of nitrogen into the cultures. The repeated transfers from the first tube to a second and from this to a third must have reduced this trace of nitrogen very considerably. However, in order to insure purity in the stock culture, transfers from these colonies were again plated on a portion of the same media and grew equally well. In this case the parallelism with the media used for the cotton was above reproach.

From all this it would seem fair to assume that the media were favorable for a development of *Ps. radicicola* had it been present in any considerable quantities upon the cotton. Isolation of *Ps. radicocola* from different legumes was carried out on this and similar media at various dates but these two cases are cited since the media and conditions were identical with those employed in the working with the cotton.[7]

PURCHASE OF COMMERCIAL CULTURES.

The purchase of commercial cultures for alfalfa, cowpea, and soy beans was made through Mr. J. B. Anderson. Packages of each were obtained from Jas. Vick's Sons, Rochester, N. Y., J. M. Thorburn & Co. and Peter Henderson & Co., New York, and J. A. Salzer, LaCrosse, Wis. These widely separated firms were expected to furnish a fair sample of the market supply. All of the packages bore the stamp and contained the advertising matter of the National Nitro-Culture Co.

[7] Four other packages from the Department laboratory were examined with entirely similar results. We do not assume, however, by stating this fact that the Department cultures have generally been worthless. That question we have not compassed in a comprehensive way. Our main purpose has been to ascertain the value of the cultures put out by commercial houses.

DATES OF PREPARATION, RECEIPT AND EXAMINATION OF COMMERCIAL CULTURES.

Label No.	Legume.	Where purchased.	Date on package.	Date received.	Examined.
2	Alfalfa........	Vick.......	4-15-05	5- 4-05	May 10, June 5, 6, 7,8
3	Alfalfa........	Henderson .	4-15-05	5- 5-05	May 10, June 5, 6, 7,8
4	Alfalfa........	Thorburn...	4-15-05	5- 5-05	May 10, June 5, 6, 7,8
5	Alfalfa........	Salzer......	4-15-05	5- 6-05	May 10, June 6, 7, 8.8
9	Soy Bean.....	Henderson .	1- 1-05	5- 5-05	May 10, 19, 25.
10	Soy Bean.....	Salzer......	1- 1-05	5- 6-05	May 10, 19, 25.
13	Soy Bean.....	Thorburn...	1- 1-05	5- 5-05	May 10, 19, 25.
14	Soy Bean.....	Vick.......	1-'1-05	5-10-05	May 10, 19, 25.
16	Cow Pea......	Salzer......	4-15-05	5- 6-05	May 10, June 13, 14.
17	Cow Pea......	Thorburn...	2-15-05	5- 5-05	May 10, June 13, 14.
18	Cow Pea......	Vick.......	1-15-05	5- 4-05	May 10, June 13, 14.
19	Cow Pea......	Henderson .	4-15-05	5- 5-05	May 10, June 13, 14.

METHOD OF MAKING THE TESTS.

It will be seen that the packages for alfalfa were all of the same date and presumably were prepared from the same stock solution at the laboratory of the company. They accordingly served as a check upon the individual determinations. The same holds true of the cotton for soy beans as well as of two of the packages for cowpea.

In making a test of the cultures about one-sixth of a package of cotton was carefully transferred to a 300-450 cc. Erlenmeyer flask containing 100 cc. of sterile, peptone-free (1.31) bouillon. The proportion of cotton to liquid was larger than is called for in the directions accompanying the package. On one occasion 200 cc. of fluid and larger amount of cotton was used. The packages for soy beans were tested at one date with bouillon from which the sugar was omitted. At one test of the packages for alfalfa the bouillon was carefully prepared from boiled water immediately before use but was not sterilized.

In all of the tests after the first one of May 10, one-half per ct. ammonium phosphate was added in sterile solution at the end of twenty-four hours.

Plates on the peptone-free (3.31) agar were usually prepared on the third day, but at times on the second or fourth day. In inoculating the plates a single transfer was made with a platinum loop from the flask to a tube of melted agar. In like manner transfers were made from this tube to a second and from the second to a third tube. The Petri dishes were enclosed in paper bags and kept at first at approximately 21° C. (70° F.) and later at 25–28° C. (77–82° F.). The plates were inspected frequently and usually recorded on the fifth and tenth days.

RESULTS OF THE TESTS.

Alfalfa.—Packages Nos. 2, 3, 4, 5. The results of nineteen examinations of the packages may be summarized as follows: In no case was there more than an occasional colony which resembled *Ps. radicicola.* A large number of these suspicious colonies as well as examples of the various types of colonies which appeared were examined microscopically by staining and hanging drop, and in doubtful cases by sub-culture. In no case did we recover cultures which appeared to be *Ps. radicicola.* A few colonies of this germ may have been present and been overlooked.

Soy bean.—Packages Nos. 9, 10, 13, 14. The results of twelve examinations were practically identical. The packages of cotton each produced an abundant growth of pink yeast and very little else. Three colonies obtained May 10 from package No. 10 were thought to be *Ps. radicicola.* This was the first examination and unfortunately this point was not fully determined.

Cowpea.—Packages Nos. 16, 17, 18, 19. The results of the twelve examinations differ from those of the other packages in some respects. It will be observed that the packages bear different dates. No. 18 was about four months old at the time of its first examination and four examinations failed to show a single colony which resembled *Ps. radicicola.* No. 17 was dated a month later, but the results of the examinations were simliar to those of No. 18. Nos. 16 and 19 were dated but a month before the first examination. In all three tests of each package there developed a considerable number of colonies resembling *Ps. radicicola* except that they had a greenish-yellow tinge, especially at the nucleus of the colony.

As a tendency to the production of a yellow pigment is noted by Sprague[8] in the case of *Ps. radicicola* from cow pea these colonies are temporarily classed as *Ps. radicicola.*

CONTROL FLASKS.

At the second examination of the cotton for alfalfa on June 5, two flasks were inoculated with stock cultures of *Ps. radicicola.* These flasks contained a portion of the same medium used in the

[8]Sprague, L. P. The Fixation of Nitrogen by Leguminous Plants, Thesis, University of Vermont, May 1, 1905.

tests of packages Nos. 2, 3 and 4. One stock culture had been isolated from an alfalfa nodule in our laboratory, while the other was that received from the Department at Washington. This came to us April 20 accompanied by the following letter:

WASHINGTON, D. C., *April* 20, 1905.

PROF H. A. HARDING,
Geneva, N. Y.

DEAR SIR :—Since writing you that it would be impossible to send you a culture for alfalfa, owing to the material being exhausted, I find that it has been necessary to make up a fresh lot of cultures. Consequently I am sending you a pure culture for alfalfa and hope it may reach you in time for your experiments.

Yours very truly,
A. F. WOODS
Chief Pathologist and Physiologist.

The appropriate amount of sterile ammonium phosphate solution was added at the end of twenty-four hours and there was a good turbidity in both flasks on the following day. Plates made on the third day gave an abundant growth in both cases of practically pure *Ps. radicicola.* Three foreign colonies were the maximum number found on any plate. The three samples of cotton, Nos. 2, 3, and 4, examined at the same time and handled in as nearly the same way as was possible did not produce a single colony which was thought to be *Ps. radicicola.*

In carrying out these tests of the cotton, there is always a short exposure to laboratory air, both in introducing the cotton and in making the plates. In order to check this factor, flasks of sterile media to which no cotton was added, received their proportion of ammonium phosphate solution and were otherwise manipulated as were the test flasks of June 6, 13 and 14. Plates from these check flasks developed only a single colony of bacteria and no yeasts. A few mold colonies also appeared.

On June 7 a similar flask received its ammonium phosphate in the form of crystals from a National Nitro-Culture Co. package. While this flask did not become turbid, a plate inoculated with a single platinum loop produced about 200 colonies of bacteria not resembling *Ps. radicicola.* On June 8 a sterile flask received 100

cc. of freshly made, but not sterile, solution (1.31). On the second day the flask showed a good turbidity. Plates gave an abundant growth, but none of the colonies resembled *Ps. radicicola.*

From the results with the control flasks of June 5 it would seem fair to suppose that the conditions in the test flasks were favorable for the development of *Ps. radicicola.* The results from the flasks of June 6, 13, and 14 render it probable that the manipulation did not introduce enough contamination to interfere with the growth of anything which may have been upon the cotton. Morever, the results with the flask of June 8 indicate that when the directions[9] are followed by the farmer, the production of turbidity on the second day is not proof that the development of *Ps. radicicola* is progressing satisfactorily.

A CO-OPERATIVE TEST OF THE COMMERCIAL COTTON CULTURES.

PLAN OF THE TEST.

The uniform failure of the commercial packages to develop vigorous cultures of the desired organism when given a favorable opportunity was a surprising result. A proper regard for the right of the parties interested demanded that these results be carefully verified before they were published. Accordingly the situation was explained to a number of bacteriologists, all of whom were more or less familiar with the organism under discussion, and they kindly consented to make check determinations of samples of cotton.

[9]DIRECTIONS FOR USING NITRO-CULTURE: *To Prepare Solution.*—Procure a jar or bottle that can be scalded out thoroughly. After cooling, fill with quantity of clean water named on package A and add the contents of packages A and B, mixing until dissolved. Cover the jar and set away in a warm, shady place, avoiding a heat greater than 100° F. At the end of twenty-four hours add the contents of package C and allow to stand until the water turns cloudy. This will usually take place in from twenty-four to thirty-six hours, depending upon the temperature. If the water has been kept very cold, it will require longer to become milky. *To Inoculate Seed.*—With the cloudy solution, prepared according to the above directions, thoroughly moisten the seed to be planted. Do not soak them. As soon as all the seed have been in contact with the solution, spread them out in a shady place to dry. When dry the seed can either be planted at once or kept on hand for several weeks without damage, *provided* they are kept dry and out of the sun. To any of the solution that may remain add one gallon of water and mix with sand or earth. This inoculated earth may then be spread over the field and be harrowed in, adding an extra quantity of Nitro-Culture to the soil.

For this co-operative work six packages of cotton were purchased from J. M. Thorburn & Co., New York, representing three legumes, the packages for each legume bearing the same date, and therefore presumably acting as a check upon the determinations.

DATES OF PREPARATION AND DATE AND PLACE OF EXAMINATION OF CULTURES IN CO-OPERATIVE TEST.

Lab. No.	LEGUME.	Date on package.	Where and When Examined.			
			Geneva, N. Y.	Newark.	New Brunswick.	Detroit.
28......	Crimson Clover..	5- 1-05	July 12...	July 18.....	July 18.....	July 28
29......	Crimson Clover..	5- 1-09	July 12...	July 18.....	July 18.....	July 28
30......	Japan Clover....	4-15-05	July 12...	July 18.....	July 18.....	July 28
31......	Japan Clover....	4-15-05	July 12...	July 18.....	July 18.....	July 28
32......	Wax Beans.....	2-15-05	July 12...	July 18.....	July 18.....	July 28
33......	Wax Beans.....	2-15-05	July 12...	July 18.....	July 18.....	July 28

Each package of cotton to be tested was divided into eight portions with sterile instruments, the work being done in a moistened Hansen inoculating chamber. Each portion of cotton was carefully wrapped in sheets of sterile parchment paper. Sets of chemicals were weighed from a common supply, which, with the exception of the sugar, were of the best grade obtainable from Eimer & Amend. Commercial granulated sugar was used. The packages of cotton and the chemicals were forwarded by express in sealed packages to avoid being tampered with in transit.

The plan agreed upon was to dissolve the chemicals in distilled water and sterilize, the di-basic ammonium phosphate being in a separate solution. The liquid in each test flask was to be one-eighth that called for by the printed directions accompanying each commercial package of cotton. After adding the portion of cotton, the flask should be held as near thirty degrees centigrade as possible. At the end of twenty-four hours the sterile ammonium phosphate solution was to be added.

According to the printed directions accompanying the cotton (See Footnote, page 63) the fluid should be used when it became milky at the end of two or three days. Plates were to be made at this time to determine the character of the growth present.

The fluid was also to be directly observed with the microscope. The medium for the plates was the same as that first placed in the flask with the addition of one per ct. agar.

The portions of cotton and packages of chemicals were sent on July 15 to Dr. J. G. Lipman, Soil Chemist & Bacteriologist to the New Jersey Agricultural Experiment Station, New Brunswick, N. J.; Dr. E. M. Houghton, Bacteriologist & Pharmacologist, Parke, Davis & Co., Detroit, Mich.; Prof. F. D. Chester, Bacteriologist of the Delaware Agricultural Experiment Station, Newark, Delaware; and Prof. C. E. Marshall, Bacteriologist & Hygienist of Michigan Agricultural College Experiment Station, Agricultural College, Michigan.

GENEVA TEST.

On July 12, the portions of cotton were placed in flasks of liquid and held at 28°–30° C. Owing to a mishap, there was no control flasks containing a stock culture of *Ps. radicicola.* After twenty-four hours the proper amount of sterile ammonium phosphate solution was added.

No turbidity was evident on July 14, but on July 15 there was a fair amount in No. 30 and No. 31, and plates were made from all the flasks. By July 17 turbidity had appeared in all the flasks except No. 28 and plates were again made from all the flasks. No turbidity appeared in No. 28 and by July 27 it was decidedly moldy.

Crimson clover No. 28.—Microscopial examination on July 18 failed to show any germ life. The plates have little growth except molds. The few colonies which appeared did not resemble *Ps. radicicola.*

Crimson clover No. 29.—Turbidity was evident on July 17 and decided on July 18. Microscope showed yeast cells common and bacteria few and non-motile. Colonies on plates were of large yeast in most cases. There was only one suspicious colony and that was also a yeast.

Japan clover No. 30.—Fair amount of turbidity July 15 and marked turbidity with bubbles of gas rising on July 19. Microscope showed yeast cells and large immotile rods fairly abundant and in about equal numbers. Both series of plates had abundant growth, a large portion of the colonies being pink yeast. About

a dozen colonies on one plate somewhat resembled *Ps. radicicola,* but the microscope showed them to be yeasts.

Japan clover No. 31.—Turbidity was fair on July 15 and decided, with bubbles of gas rising, on July 19. The microscope showed the presence of many yeast cells and a few bacteria. The plates developed abundant growth which was practically all pink yeast. No colonies of *Ps. radicicola.*

Wax beans No. 32.—A faint turbidity was evident July 17 and this was decided the following day. The microscope showed a fair number of yeast cells and no bacteria. The first set of plates produced about 150 colonies and the second set had a more abundant growth, but none resembled *Ps. radicicola.*

Wax beans No. 33.—A slight turbidity appeared July 18. Microscopic examination showed a few bacteria, part of which were motile, but no yeasts. The second series of plates gave a good growth. A single colony was thought to be *Ps. radicicola.*

NEW BRUNSWICK REPORT.

The report from Dr. Lipman is dated July 31, 1905.

"Your packages of cotton, marked respectively:—Nitro culture 28, 29, 30, 31, 32 and 33, as well as the accompanying salts for the nutrient solutions reached me on Monday, July 17. In accordance with your instructions of July 8, the nutrient solutions were made up by dissolving the salts in distilled water in the proportions specified, and distributed in the proper quantities in 500 cc. Erlenmyer flasks. The ammonium phosphate was dissolved separately, and everything sterilized in the autoclave at two atmospheres of pressure.

"Inoculation was made with proper precaution against infection on July 18; and on July 19, that is at the end of 24 hours, the corresponding amounts of ammonium phosphate were added. In the morning of July 20 there was still no sign of growth in any of the flasks, but in the afternoon of the same day the solutions 30 and 31 showed a slight cloudiness. Examination in hanging drop showed the growth in 30 to consist largely of short, stout rods very similar in appearance to *B. megaterium,* and also of long slender bacilli.

"On July 21 cultures 28 and 29 were still clear; 30 strongly cloudy; 31 slightly cloudy; 32 clear; 33 cloudy. On July 22

culture 28 was still clear; 29 slightly cloudy; 30 turbid; 31 cloudy; 32 clear; 33 strongly cloudy. Examination in hanging drop revealed nothing in 28; a few long irregular rods in 29; the *B. megatherium*-like organisms, and the long rods already noted, as well as some short motile rods in 30; a few yeast cells and short spore-bearing rods in 31; nothing in 32; small motile rods in 33. None of the organisms observed in any of the cultures resembled *P. radicicola.*

"On July 24 the macroscopic appearance of the different cultures was practically unchanged, except that a small mold appeared in 28. Further examination failed to show the presence of *P. radicicola.*

"Agar plates from 30 and 33 were prepared on July 22. On July 24 the colonies on these plates were well developed, and consisted of the organisms already noted in the hanging drop preparations from the corresponding cultures. Continued observation for another week of both liquid cultures and plates, as well as the numerous hanging-drop preparations from different colonies failed to reveal the presence of *P. radicicola.*

"It was safe to assume from the above evidence that there was no growth of *P. radicicola* under the conditions of the experiment, and that the failure of such growth to appear was due either to the absence of *P. radicicola* in the inoculating material, or to the unsuitability of the culture media used for the development of this organism. To check this matter a freshly isolated culture of *P. radicicola* from alfalfa tubercles, which made satisfactory growth on the agar used, was inoculated into one of the culture solutions. The latter was treated precisely as were the others. No sign of growth appeared at the end of three days and a further quantity of *P. radicicola* was therefore introduced into the solution. At the end of five days the latter was still clear and showed no sign of growth.

"It thus appeared that the culture solutions used were not adapted to the growth of *P. radicicola* and that the failure of such growth to appear could not justly be attributed to the absence of *P. radicicola* in the inoculating material. The results are manifestly inconclusive and it is believed that better results would have been obtained had sterile tapwater been used instead of distilled water. The latter was used, notwithstanding the mis-

givings on my part, for it was desirable to follow your directions closely that comparable results might be secured.

"Meanwhile it was decided as a check on the above experimental work, to secure other cultures in the open market, and to inoculate these into parallel tapwater and distilled water solutions, otherwise following the printed directions as furnished by the Nitro-Culture Company. Accordingly on July 18 two packages of nitro-culture were purchased at the Henderson store on Cortlandt street, New York city. One of these was for crimson clover and was dated May 1, 1905, the other was for soy beans, and was also dated May 1, 1905. The salts found in this package were used to make up two solutions, one in distilled water, the other in tapwater. The ammonium phosphate (package marked C) was dissolved separately. The solutions were sterilized in the autoclave, cooled and inoculated, the ammonium phosphate being added with a sterile pipette at the end of twenty-four hours.

"Without going into detail, it is sufficient to state here that the tapwater cultures made rapid growth, and were turbid at the end of twenty-four hours after the addition of the ammonium phosphate. The distilled water cultures made very slow growth, but finally became cloudy at the end of four or five days. Hanging drop preparations, as well as the agar plates prepared from these cultures, failed to show the presence of *P. radicicola* at any time.

"Taking the two experiments together, it would seem that while the results with nitro-cultures 28, 29, 30, 31, 32 and 33, were inconclusive, those secured with the crimson clover and the soy bean cultures would indicate that *P. radicicola* was either absent in the cotton supplied by the company or would not develop (when present) even under the conditions called for by the printed directions accompanying each package. Further comments are unnecessary, although in justice to all concerned, it would be no more than proper to check the work once more." (See page 81.)

DETROIT REPORT.

Dr. Houghton sent his report September 4, 1905. In this case the laboratory work was done by Mr. L. T. Clark.

SYNOPSIS OF WORK ON SAMPLES OF INOCULATED MATERIAL FROM DR. HARDING, OF GENEVA, N. Y.

By L. T. CLARK.

Prepared solutions as per directions, namely:

Cane sugar....................................	18 gm.
Potassium phosphate (mono)......................	2 gm.
Magnesium sulphate..............................	1 gm.
Distilled water.................................	1900 Cc.

This solution was put into ½-litre Florence flasks, 235 Cc. in five flasks and 118 Cc. in two flasks, to correspond to size of bits of cotton received, and the flasks properly sterilized. Opened packages containing samples of cotton very carefully, taking precautions to exclude dust and other foreign material, and dropped the bits of cotton into the flasks of sterile solution, and labeled flasks to correspond to numbers on packages. Set flasks in temperature of 28° C. Examined at the end of twenty-four hours, noted turbidity, and recorded same. At this recording, added enough sterile ammonium phosphate solution to give the solution in the flasks .5 per ct. of the pure salt, and then allowed to develop further. Examined flasks at intervals of twenty-four hours and recorded changes whenever such was necessary.

At the end of four days plated proper dilutions in agar (one loop from flask to first tube and two loops from first to second tube) from each flask. Defective plates (porcelain covers) rendered these results worthless.

At the end of seven days another set of plates was made from which the final records were taken. To avoid any possible error in identifying the characteristic colony of *P. radicicola*, check flask and plates of *P. radicicola* from cow-pea (Migge,—tube culture) was carried along parallel with the six from Geneva.

Colonies appearing on the plates at the end of seven days were examined with low power, compared with check plate from tube culture (Migge) and their purity recorded.

For personal satisfaction the same dilutions as used above were plated from each flask in a special agar, upon which the true colony of *P. radicicola* can be more easily identified. The results secured from these plates bore out the results already recorded

so closely that such differences as existed could be readily attributed to error of experiment.

The detailed report of the cultures was as follows:

"*Check Flask* inoculated with laboratory culture: Turbidity intense with some sediment at the end of three days. Plates showed characteristic colonies of *P. radicicola* and no contamination. Culture pure.

"*Crimson clover No. 28.*—Turbidity slight at the end of twenty-four hours but not dense at the end of three days. Plates showed purity of culture approximately 50 per ct.

"*Crimson clover No. 29.*—Turbidity slight at end of twenty-four hours and decided, but not dense, at the end of three days. Plates showed no characteristic colonies of *P. radicicola.*

"*Japan clover No. 30.*—Very faint turbidity at the end of twenty-four hours, which became very decided at the end of three days. Plates gave colonies uniform and true in character to *P. radicicola.* Culture pure.

"*Japan clover No. 31.*—Faint turbidity at the end of twenty-four hours, which became decided at the end of three days. Plates showed colonies not uniform and few characteristic. Some yeast and many 'off' colonies. Culture impure.

"*Wax bean No. 32.*—No turbidity had appeared at the end of three days. Plates gave few colonies, 75 per ct. of which were yeasts and 25 per ct. *P. radicicola.* Culture weak and impure.

"*Wax bean No. 33.*—Decided turbidity at the end of three days. Plates gave numerous and uniform colonies of *P. radicicola* and no contamination of 'off' germs. Culture pure."

SECOND DETROIT REPORT.

A second set of cotton samples was forwarded to Dr. Houghton Oct. 4, and the following report received Nov. 10, 1905.

SYNOPSIS OF WORK ON SAMPLES OF INOCULATING MATERIAL FROM DR. HARDING, GENEVA, N. Y.—SECOND SET OF DETERMINATIONS. OCTOBER 23, 1905.

Received set of samples Oct. 6, 1905. Prepared culture solution as per Harding directions, namely:

Cane Sugar	18 grams.
Potassium Phosphate (mono)	2 grams.
Magnesium Sulphate	1 gram.
Distilled Water	1900 Cc.

Filled this solution into one-half L. flasks, 235 Cc. in each flask, and thoroughly sterilized.

Prepared a quantity of nitrogen free agar, to be referred to as "Special" No. 5 and also a quantity of nutrient agar "Special" No. 4. The latter is a medium found to be especially valuable in identifying the organism sought. A preliminary test proved the Special No. 5 to be superior to the nitrogen free agar recommended by Dr. Harding as it promotes a more rapid development of *P. radicicola,* although a nitrogen free medium.

On Oct. 9 planted the bits of cotton in flasks labelled to correspond to number on package. Also planted two similar flasks with a vigorous pure culture of *P. radicicola* from Garden Pea, these latter flasks to be known as "Check" I and II.

Oct. 11, or forty-eight hours after planting bits of cotton, one-half per ct. of Ammonium Phosphate, dibasic, was added to the flasks. After twenty hours' growth in the presence of Ammonium Phosphate, at which time the solution should have become decidedly turbid and ready to use as a practical product, samples were drawn off by means of sterile pipettes and centrifuged and the sediments used in making smear stains.

Proper dilutions from the eight flasks (8) were plated in Series I "Special" agar No. 5 (nitrogen free) and in series II "Special" agar No. 4 (nutrient) at the end of forty-eight, seventy-eight and two hundred and sixty-four hours respectively. Allowed plates to develop ninety-six hours at a temeprature of 26° to 28° C. before recording results. At intervals of twenty-four, forty-eight, ninety-six, one hundred and twenty, one hundred and forty-four and two hundred and fifty-six hours respectively, the turbidity appearing in the eight flasks was recorded.

"From the results of the above described methods of operation the following summary for each sample has been collected:

"*Sample No. 28.*—Faint milkiness in forty-eight hours. No change or increase until eleventh day, when contaminations predominated. Plates and slides revealed few molds and yeasts. No *P. radicicola* present.

"*Sample No. 29.*—Same as No. 28. Plates and slides, nearly pure culture of yeast. One bacteria and few molds. No *P. radicicola* present.

Sample No. 30.—Milkiness faint in forty-eight hours. Increased after forty-eight hours when Ammonium Phosphate was added. First set of plates possessed a single colony of *P. radicicola,* also a large number of yeast colonies. Organism isolated from the one characteristic colony proved to be vigorous and strong.

"*Sample No. 31.*—Same as No. 30. Plates developed a great many yeasts and several colonies of bacteria. No *P. radicicola* present.

"*Sample No. 32.*—Solution remained clear until tenth day when a faint milkiness appeared, due to a pink yeast. No *P. radicicola.*

"*Sample No. 33.*—Solution remained perfectly clear throughout. Plates and slides free from organisms.

"*Check I and II.*—Solution became milky at the end of twenty-four hours, which condition continued to increase until it became opaque. Plates and slides showed pure culture of *P. radicicola.*

"*Conclusions.*—Two samples out of the six, No. 32 and No. 33, were practically sterile and only single colony of the nitrifying organism, *P. radicicola,* could be detected, even when submitting the solutions to dilution platings in two media. The yeast found so commonly in the samples proved to be a non-fermenting organism of high vitality, producing a colony with a somewhat transparent margin and dirty, greenish-yellow center at first, later becoming dense and opaque with a raised, glistening surface. From the fact that this organism was found identical in samples Nos. 28, 29, 30 and 31, and in large numbers, leads us to suspect its origin in the original inoculating solution, or in the cotton which was impregnated. Its growth in nitrogen free solutions produced a uniform milkinesss not unlike that of *P. radicicola,* although slower and without the formation of pigment so common of the wild yeasts, hence its liability of being mistaken for a growth of *P. radicicola.*

SUMMARY OF THE TWO DETROIT REPORTS.

TEST OF NITRO CULTURES. I.

July 28 to Aug. 12, 1905.

Flask.	Flasks Turbidity Recorded.			Plates P. Radicicola.		Slides. Hanging Drop.
	Hours 24.	Hours 72.	Hours 360.	Hours 96.	Hours 168.	
28	Faint milkiness.......	Cloudy......	Turbid......	Results lost..	50%........	Yeasts and Bact.
29	Faint milkiness.......	Cloudy......	Turbid......	Results lost..	None........	Yeasts.
30	Very faint milkiness..	Turbid......	Turbid......	Results lost..	100%.......	Bact.
31	Very faint milkiness..	Cloudy......	Turbid......	Results lost..	Very few.....	Yeasts.
32	None........	None........	Very cloudy .	Results lost..	25%.......	Yeasts and Bact.
33	None........	Cloudy......	Turbid and gas........	Results lost..	100%.......	Bact.
Check...	None........	Turbid......	Turbid and gas........	Results lost..	100%.......	Bact.

TEST OF NITRO CULTURES. II.

Oct. 9 to 23, 1905.

Flask.	Flasks. Turbidity Recorded.					
	Hours 24.	Hours 48.	Hours 96.	Hours 120.	Hours 144.	Hours 264.
28	None........	Very faint milkiness..	Same........	Same........	Same........	Contam'd molds
29	None........	Very faint milkiness..	Same........	Same........	Same........	Contam'd molds
30	None........	Very faint milkiness..	Faint milki-milkiness..	Same........	Milky.......	Turbid sediment
31	None........	Very faint milkiness..	Faint milki-enss.......	Same........	Milky.......	Cloudy
32	None........	None........	None........	None........	None........	None
33	None........	None........	None........	None........	None........	None
Check I.	Faint milkiness.......	Milky.......	Very milky...	Cloudy......	Turbid sediment......	Same
Check II	Faint milkiness.......	Milky.......	Very milky...	Cloudy......	Turbid sediment......	Same

TEST OF NITRO CULTURES. II.

Oct. 9 to 23, 1905.

Flask.	PLATES. *P. radicicola.*			SLIDES. STAINS—CENTRIFUGED SAMPLES.		
	Hours 48.	Hours 78.	Hours 264.	Yeasts.	Bact.	Branched forms.
28	0	0	0	+	0	0
29	0	0	0	+	+	0
30	+ Single colony	0	0	+	+	3
31	0	0	0	+	+	+
32	0	0	0	No micro-organisms		
33	0	0	0	No micro-organisms		
Check I	+	+	+	0	+	+
Check II	+	+	+	0	+	+

"I am sending you herewith a complete report of our latest examination. I regret that our work here should not have checked up as closely as that of the other workers. Certain it is, great care was exercised in carrying out the work, and we are unable to satisfactorily explain the discrepancy. A few days ago, however, in making an examination of the distilled water we employed we found that it contains about one part of albuminoid ammonia to one million of water. This may have had a beneficial effect upon the culture media by influencing the growth of germs in the material that was sent in July. From our detailed report sent you in September, you will see that the cultures at best were not very vigorous. A little coaxing, as would be exercised by a little ammonia in the culture media, may have been sufficient for us to obtain a growth, while, if it had been absent no growth would have occurred. This seems to me the most reasonable explanation of the discrepancy. It would be interesting to know just what conditions the material was kept under before the examinations were made.[10] I do not recall just when you sent the first lot of material to me, but indistinctly remember that it was kept, after its receipt, for some time in a cool place, away from the sunlight, until my assistant, Mr. Clark, came the latter part of July. I can readily understand that, if the material was placed in the sunlight or even in

[10]The portions of cotton while at Geneva were inclosed in the paper boxes in which they were purchased and stored in a dark corner of our dimly lighted culture room which is held at approximately 17° C. (65° F.).

a warm room at that time of the year, the germs might die out even more quickly than if kept in a cool place where the temperature did not fluctuate too much. There seems to be no question but that the cultures rapidly deteriorate. This is shown very conclusively in our two examinations."

NEWARK REPORT.

The report of Prof. Chester is dated September 4, 1905.

"Enclosed please find notes covering the examinations of the Nitro-cultures. The cultures are all innocent of *Ps. radicicola* except No. 33, Wax Bean, and even this was a very weak specimen. I am sorry that I did not fully finish No. 31. I thought at first that this, like No. 30, was going to prove sterile, when, after six days, a slight growth appeared in the flasks. I was unable to conduct the experiment from this point as I had made arrangements to leave for New York State.

"I feel quite sure, however, that no living *Ps. radicicola* were present on the cotton, and that the growth was due to some foreigner which develops very slowly in the nitrogen-poor medium.

"The media were made in full accordance with your directions.

"Medium 48 is the fluid medium for starting the culture, and 48 agar, the latter plus 1 per ct. agar. I think, however, that 1 per ct. agar is not quite enough, making it too soft; I prefer 1.2 per ct. or 1.5 per ct."

The details of the work are as follows:

"*Crimson clover Nos. 28 and 29.*—No growth in flasks in six days and no plates made. Conclusion: Cotton apparently sterile.

"*Japan clover No. 30.*—Turbidity strong at the end of two days. Microscopic examination showed long motile rods of the *B. subtilis* type, and short coiled chains of the *B. ruminatus* type, but none of the *Ps. radicicola* type. Plates were made on 48 agar and on plain agar. On medium 48 agar, colonies all of *B. ruminatus* (*B. subtilis* Gr.) No *Ps. radicicola* colonies. On plain agar colonies of *B. subtilis* and *B. ruminatus*. Conclusion: Cotton contains no living *Ps. radicicola,* and only spores of two members of the *B. subtilis* group, i. e.: *B. subtilis* and *B. ruminatus,* both common terrestrial forms.

"*Japan clover No. 31.*—Owing to my departure from home, I was unable to make plates from this culture, which showed but

faint growth after six days. The cotton is, however, probably sterile so far as *Ps. radicicola* is concerned, as the latter germ grows readily in medium 48, and would likely have developed sooner had it been present.

"*Wax bean No. 32.*—Turbidity moderate on third day. Microscope shows long, actively motile rods of *B. subtilis* Group. None of the *Ps. radicicola* type. Plates showed colonies of *B. ruminatus,* none of *Ps. radicicola.* Conclusion: Contains no living *Ps. radicicola* and only spores? of two common members of the *B. subtilis* group.

"*Wax bean No. 33.*—Moderate turbidity on the third day. Plates on 48 agar showed colonies of a small polymorphic bacillus which stained brown with iodine—*Ps. radicicola?* Plates on plain agar showed colonies of *B. asterosporus,* and a small polymorphic bacillus. Conclusion: Cotton probably contains a few living *Ps. radicicola.*

"The cultures from cotton included in the preceding tests were made from media prepared from distilled water.

"The failure to obtain a growth of *Ps. radicicola,* in most cases, was, I believe, not due to any deficiency on the part of the medium. Cultures of alfalfa and crimson clover bacteria, dried on cotton gauze, very recently prepared in this laboratory from pure cultures, were inoculated into a portion of the medium used in the preceding tests. There was in each case an abundant growth, especially after the addition of the ammonium phosphate, and plates made with 48 agar gave typical *Ps. radicicola* colonies.

"In fact I have been able to grow *Ps. radicicola,* although the growth is more feeble, in media made from ammonia-free distilled water.

"From this it is reasonable to assume that had *Ps. radicicola* been present on the specimens of cotton it would have developed in the cultures made therefrom.

"In the previous notes I have spoken of the cotton as sterile or as containing no living *Ps. radicicola.* This statement has only a relative significance. The organism may be entirely dead, or it may have only have had its viability so reduced that it fails to develop in the culture medium, singly or along with other

contending forms, in the period covered by the experiment, which in the usual period covered in the preparation of cultures by the farmer."

WERE THESE TESTS FAIR TO THE COTTON?

In using this laboratory work as a basis for predicting what will happen when the cotton is used by the farmer there are two differences in the conditions which should not be overlooked.

In the first place the cotton at the laboratory was handled with sterile instruments, placed in sterile solutions and continually protected from contamination. At the farm the cotton itself can hardly escape some contamination and will be placed in "clean water"[11] which, on the farm, is never sterile and is often abundantly supplied with germ life. The chemicals will also carry their quota of germs. Due to the farmer's lack of familiarity with the delicate process which he is superintending, the exposure which will often occur during the two or three days of the culture's growth will in itself be sufficient to markedly endanger the result.[12]

It seems but a fair deduction that by keeping out all forms of germ life except that originally upon the cotton, the laboratory conditions have been in this respect far more favorable for the development of *Ps. radicicola* than can be reasonably hoped for upon the farm.

In the second place the water used at the laboratory and upon the farm was not alike, that at the laboratory being distilled water, while that at the farm would be rain or wellwater of quite variable composition. An important variation lies in the content of nitrogen.[13]

Distilled water had been chosen for our own laboratory work partly because it was the water used in all other culture media and more especially because it was indicated in the letters patent of Dr. Moore. Its use was continued in our coöperative test as the kind of water which would be most nearly alike at all the laboratories.

Experiments have repeatedly demonstrated the ability of *Ps. radicicola* to develop when this water was used in preparing the

[11] See Nitro-Culture Co's direction given as footnote on page 63.
[12] Note the result with the control flasks, page 79.
[13] Thorp's Dictionary of Applied Chemistry, **3**:939=994.

media. It should, however, be noted in this connection that in a single case a quantity of this media did not appear to be a satisfactory substrate for growth, although *Ps. radicicola* grew upon it in some cases. The reason for this condition was not discovered. The experiment of Dr. Lipman was unfortunately a similar case, while Dr. Houghton and Prof. Chester, using the same chemicals but other samples of distilled water, obtained abundant growth with stock cultures of *Ps. radicicola.*[14]

REPETITION OF TESTS USING RAINWATER OR TAP-WATER.

RETEST OF PACKAGES NOS. 2 TO 19.

In accord with Dr. Lipman's suggestion (see page 68) it seemed best to continue the test, using water which would more nearly represent farm conditions. Media were prepared, using the same chemicals as before dissolved in our city water. The water is derived partly from Seneca lake and partly from springs. During sterilization a copious precipitate, accompanied by a marked and persistent milkiness was formed. On this account the solution was unfit for use. Practically the same result followed the use of the water from a local well. A similar precipitation was obtained at Dr. Marshall's laboratory where an artesian water was used. The tap water at Dr. Lipman's laboratory is derived from a number of small streams flowing partly over the red shale formation. The precipitate formed in the use of the water does not interfere with the work since the sterile nutrient solutions become quite clear on standing.

Rainwater was tried with better success. A slight milkiness appeared upon sterilization, but this almost completely disappeared upon cooling. The amount of this turbidity varied slightly with samples from different sources. The fluid prepared in this way from rainwater was designated as 1.34 and the corresponding agar as 3.34.

On August 9, portions of packages Nos. 2, 3, 4 and 5 were placed in sterile fluid 1.34. Turbidity developed less rapidly but was good in No. 3 and fair in Nos. 2, 4 and 5 at the end of three

[14]See Prof. Chester's report, page 75.

days. The microscope showed yeasts to be most numerous in all but No. 2. Plates made on agar (3.34) gave abundant growth in all cases. One colony from No. 2 and three colonies from No. 5 resembled *Ps. radicicola.* None similar was found on the plates from Nos. 3 and 4.

On August 10, samples from packages 10 and 14 were likewise tested in sterile fluid (1.34). No turbidity had appeared at the end of five days and plates inoculated from the fluid produced practically no growth.

Three very interesting check flasks were run at the same date. One flask contained the proper chemicals dissolved in clean well-water according to the directions on the commercial packages. A second flask of fluid was prepared in the same way except that clean rainwater was used. Neither flask was sterilized. At the end of two days both flasks had developed a good characteristic turbidity although neither flask had received either cotton or ammonium phosphate.

The third check flask contained sterile fluid (1.34) and was inoculated with four drops of tapwater. This flask received its proper amount of sterile ammonium phosphate solution at the end of twenty-four hours. At this time a slight turbidity was evident and this became very decided by the end of the second day. Most interesting of all, plates from this flask showed a nearly pure culture of an organism producing colonies which very closely resembled *Ps. radicicola.*

Another set of six flasks, each containing 150 Cc. of sterile (1.34) bouillon received 1, 2, 4, 8, 16, 20 drops of tapwater respectively. Each of the flasks became turbid within thirty-six hours. The agar plates from these flasks showed a large number of colonies resembling *Ps. radicicola.*

On August 13, samples from Nos. 16, 17, 18 and 19 were placed in sterile fluid (1.34). No turbidity had appeared in Nos. 16 and 19 at the end of three days, and plates failed to develop any colonies resembling *Ps. radicicola.* In flasks Nos. 17 and 18 the turbidity was good at the end of three days when the plates were made. The growth on the plates was abundant and on those from No. 17 a few colonies resembled *Ps. radicicola.* None of the colonies from No. 18 resembled it.

SECOND CO-OPERATIVE TEST.

GENEVA TEST.

August 8, portions of packages No. 28-33 were placed in the appropriate amount of sterile fluid (1.34). Turbidity came on very promptly; Nos. 28, 30 and 31 developed a good turbidity by the end of two days, and Nos. 29, 32 and 33 at the end of three days. Microscopical examination showed the bacteria to be much more numerous than the yeasts in all cases except No. 29. The plates showed the pink yeasts to be present in Nos. 30 and 31. From Nos. 28, 30, 31 and 33 a few colonies resembled *Ps. radicicola* in gross appearance, but the germ was a plump granular bacillus. Pending a further determination of the character of this germ, the cotton should be given the benefit of the doubt. No thoroughly typical colonies of *Ps. radicicola* were found.

MICHIGAN AGRICULTURAL COLLEGE REPORT.

This test was made at Dr. Marshall's laboratory by his assistant Mr. W. G. Sackett. Dr. Marshall states that all the credit should be given to Mr. Sackett who has checked the work in every way possible and has done everything very carefully.

Freshly caught rainwater was used in making the media and the chemicals were from the same supply used in all of the coöperative experiments.

The portions of cotton were added to the sterile solution October 20, sterile ammonium phosphate solution was added October 21, and plates were made from all the flasks on October 22, 23 and 25.

All control flasks were inoculated with a freshly isolated culture of *Ps. radicicola* (soy bean) and were kept under precisely the same conditions as the cultures in question. These showed a distinct turbidity after forty-eight hours and plates made from the same developed true *Ps. radicicola* colonies.

The detailed report on the various samples follows:

"*Crimson clover No. 28.*—No turbidity developed by October 25. No growth on any of the plates.

"*Crimson clover No. 29.*—Slight turbidity October 25. Microscope showed many yeasts. Many colonies of yeasts appeared upon the plates but none of bacteria.

"*Japan clover No. 30.*—Solution became turbid October 23. Microscope showed many yeasts but no bacteria. Plates showed many yeast colonies, a part of which were pink. No bacterial colonies appeared.

"*Japan clover No. 31.*—Turbidity was slight on October 23, and decided on October 25th. Microscope showed many yeasts and no bacteria. Plates developed many colonies of yeasts but none of bacteria.

"*Wax bean No. 32 and 33.*—Flocculent turbidity appeared in each flask October 25. Microscope showed these to be masses of a short plump bacillus. No yeasts appeared upon the plates and but few bacterial colonies."

SECOND NEW BRUNSWICK REPORT.

A second set of samples of cotton and chemicals was furnished to Dr. Lipman who presented the following report October 30, 1905:

"The cotton cultures, 28, 29, 30, 31, 32 and 33 received on October 23, were inoculated into the nutrient solution made up according to the directions and all the solutions were made up with tapwater. As a check on these cultures, I also inoculated into a sterile portion of the nutrient solution, a pure culture of *P. radicicola,* isolated from soy bean tubercles, and sent to me by Mr. Karl Kellermann. All of the cultures were kept in the incubator at 27° for three days, and for three additional days after that at room temperature. The check culture showed cloudiness at the end of eighteen hours even before the addition of the ammonium phosphate, and was strongly turbid at the end of forty-eight hours. The six cultures were all clear at that time, and showed no growth. At the end of three days, cultures 30 and 31 were slightly cloudy; the others still clear. At the end of six days, 28, 29, 32 and 33 were still clear, while 30 and 31 were cloudy. The latter, when examined under the microscope, contained medium-sized spore-bearing bacilli, and clostridia. It was not found necessary, in view of the above, to prepare plates from any of the cultures. These observations taken together with those previously reported to you, lead me to the belief that the cotton cultures 28, 29, 30, 31, 32 and 33 contained no *P. radicicola* organisms capable of development under the conditions prescribed by the manufacturers."

WHY USE STERILE MEDIA?

It may seem strange that we did not propagate the cotton in unsterilized media just as would have been done on the farm, and then determine the character of the growth in the fluid at the stage when it would have been used by the farmer. We did so in a number of cases and while we believe the results are in strict accord with those presented, we have not laid stress on them for the following reasons.

It seemed to us that by cutting off the competition which would have existed between the germs in the unsterilized media and the germs upon the cotton, the latter have had a much more favorable opportunity for development than they could have had under farm conditions.

In unsterile media the milkiness which is relied upon to indicate the time for using the solution appears promptly, even when the cotton is not present. Therefore, no reliable conclusions can be drawn from its appearance in unsterile media, when the cotton is present.

A majority of the colonies which develop from unsterile media, to which the cotton has not been added, very closely resemble those produced by *Ps. radicicola.* When the cotton has been placed in this unsterile media, a microscopic examination of each colony is necessary before it can be said with a certainity that it is not *Ps. radicicola.* This markedly increases the labor of examining the plates and to a corresponding degree makes the value of the conclusion depend upon the quality of judgment displayed in the examination.

When using sterile media in our examinations, if all suspicious colonies were classed as *Ps. radicicola,* they would not represent a sufficient number in the fluid to be of any value for practical purposes.

DESSICATION OF Ps. RADICICOLA ON COTTON.

Our repeated failures to obtain satisfactory growth of *Ps. radicicola* from the commercial cotton led us to doubt the viability of the germ.

First test.—A package of Johnson's absorbent cotton was procured from a local dealer and a layer of the cotton cut into sq. cm. blocks. These blocks were enclosed by fives in Petri dishes

and sterilized in dry heat for two hours at 135 degrees C. Each block received $\frac{1}{20}$ cc. of a (1.31) bouillon culture prepared as follows: *Ps. radicicola* derived from the Department stock culture was cultivated three days on 3.31 agar when a good growth had appeared. The growth from a single slope was carefully broken up in sterile water and transferred to 200 cc. of sterile (1.31) bouillon. At the end of three days the bouillon became faintly cloudy and one-half per ct. sterile ammonium phosphate was added. Nine days later, June 19, the bouillon culture was used for inoculation.

A set of (3.31) agar plates was made to determine both the purity of the culture and approximately the number of germs placed upon each square of cotton. The plates developed a typical growth representing a content in the (1.31) bouillon of 13,000,000 per cc. and the addition of 650,000 to each square of cotton.

The Petri dishes containing the inoculated cotton were enclosed in paper bags and stored in a drawer in the laboratory. Here they were exposed to approximately the same dessication as would be experienced by the commercial packages.

Between June 20 and July 6, fifty of the inoculated cotton squares were examined. In the earlier examinations, a cotton block was placed in a Petri dish, 10 cc. of (1.31) agar was poured over the cotton, and the plate was gently agitated. Later the blocks were spread over the bottom of the dish with sterile needles and the agar added. On these fifty plates there was an average growth of three colonies. About one-half of these colonies resembled *Ps. radicicola* and the remainder were yeasts and chromogenic colonies, probably derived from the air while preparing the plates. Not a single colony developed on the last fifteen plates.

The details of the first experiment were not entirely satisfactory. The bouillon culture used for inoculating the cotton was twelve days old and its vitality may have become reduced. The absorbent cotton may have undergone some treatment which rendered it unfavorable to germ life. The media were all prepared with distilled water which is not so favorable to germ growth as rainwater.

Second test.—Through the courtesy of Johnson & Johnson, New Brunswick, N. J., we were furnished with a package of their best absorbent cotton which they assured us had not been exposed to any chemicals which would render it harmful to germ life. The media in this test were prepared with rain-water.

The details of this second experiment were the same as those of the first, except that no ammonium phosphate was added, the (1.34) bouillon culture used for inoculating the cotton was four days old, and two series of cotton squares were inoculated. One series was inoculated from the culture used in the first experiment, while the second series received a germ isolated in our laboratory from an alfalfa nodule.

The cotton was inoculated August 19 and plates on (3.34) agar indicated that each square received over 1,000,000 germs.

Two weeks later (3.34) agar plates were made from five squares of cotton from each series. In each case a square of cotton was spread evenly over the bottom of a Petri dish and agar added. The plates were practically sterile at the end of seven days. Ten more plates made in a similar manner gave similar results. Now and then a colony resembling *Ps. radicicola* would develop on the plates, but in no case did more than eight typical colonies develop from a single cotton square. It was evident that either the bacteria were practically all dead upon the cotton or were in such a weak condition that they could not grow in the (1.34) agar.

Instead of placing the cotton directly in the agar, blocks were now transferred to tubes containing 10 cc. of sterile (1.34) bouillon and incubated at 26° C. (79° F.) for various intervals before plating.

Five blocks were thus treated on October 5, 10, and 16, and plates made at the end of 4 hours, 24 hours and 2 days. In each case the total contents of the tube was divided among a number of plates so that all of the germs upon the cotton or developing from it should be obtained. While the results varied slightly with the various squares, the results from these 15 squares of cotton may be summed up as follows: The plates made after incubating four hours showed from eight to 300 typical colonies from each block of cotton. Plates made at

the end of 24 hours showed a fairly abundant growth representing a number of hundred germs. Between the third and the seventh day the material in the test tube became cloudy and the plates showed the presence of very large numbers of *Ps. radicicola.* This rapid multiplication may seem surprising, but Rogers[15] has found that under favorable conditions in pasteurized milk, approximately 1,000,000 germs are produced from a single germ in three days.

GENERAL OBSERVATIONS.

There is nothing in this bulletin which should be construed as opposed to the idea of inoculating legumes with *Ps. radicicola.* This publication concerns itself solely with the quality of the cotton cultures which have been used the present season.

Failure has followed each of our attempts to develop cultures of *Ps. radicicola* from the commercial cotton cultures. These failures could not well be ascribed to the laboratory methods employed by us, since the same method was uniformly successful when laboratory cultures of *Ps. radicicola* were used in the place of cotton cultures.

The results of our colleagues reached in widely separated laboratories strongly support our findings.

The explanation for this surprising condition of the cotton lies in the inability of *Ps. radicicola* under ordinary atmospheric conditions to maintain itself upon the cotton for any considerable time.

The use of unsterile water, chemicals and utensils at the farm together with the contamination already present on the cotton exposes the few surviving *Ps. radicicola* to a fierce struggle for existence.

The results with the commercial cotton do not show necessarily that all the *Ps. radicicola* were dead. They merely show that the germs were so few as to make no observable headway against the competition of the other germs present.

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[15]Rogers, L. A. Bacteria of Pasteurized and Unpasteurized Milk under Labaratory Conditions. Bureau of Animal Industry, Bul. 73:25. 1905.

REPORT

OF THE

Botanical Department.

F. C. Stewart, *Botanist.*

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[1]H. J. Ramsey, *Student Assistant.*

F. A. Sirrine, *Special Agent.*

TABLE OF CONTENTS.

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[1]Resigned June 24, 1905.

REPORT OF THE BOTANICAL DEPARTMENT.

POTATO-SPRAYING EXPERIMENTS IN 1904.*

F. C. Stewart, H. J. Eustace and F. A. Sirrine.

SUMMARY.

During 1904 the Station made potato-spraying experiments on a large scale. This bulletin gives the details of 58 different experiments in various parts of the State.

In the Station ten-year experiments the gain due to spraying was larger than ever before. At Geneva, five sprayings increased the yield 233 bushels per acre, while three sprayings increased it 191 bushels. The gain was due chiefly to the prolongation of growth through the prevention of late blight. The sprayed potatoes contained one-ninth more starch and were of better quality. At Riverhead, the gain due to six sprayings was 96 1-3 bushels and to three sprayings 56 1-2 bushels per acre. Here, the flea-beetle was the chief enemy.

In fourteen farmers' business experiments, including 180 acres, the average gain due to spraying was 62 1-4 bushels per acre; the average total cost of spraying, $4.98 per acre; the average cost for each spraying, 93 cents per acre; and the average net profit, based on the market price of potatoes at digging time, $24.86 per acre.

In 41 farmers' volunteer experiments, including 363¾ acres, the average gain due to spraying was 58½ bushels per acre. In 23 of these experiments the average total cost of spraying was $3.91 per acre; the average cost for each spraying 90⅔ cents; and the average net profit, based on the market price of potatoes at digging time, $22.01 per acre.

*A reprint of Bulletin No. 264.

Soluble bordeaux, a fungicide devised by Dr. S. M. Babcock of the Wisconsin Station, and soda bordeaux were compared with the regular lime bordeaux. Soluble bordeaux increased the yield 11 bushels per acre; soda bordeaux, $51\frac{2}{3}$ bushels per acre; and lime bordeaux, $68\frac{1}{3}$ bushels per acre. The disease fought in this experiment was late blight. It may be that the soluble bordeaux was used in too dilute a solution. Soda bordeaux is not to be recommended, at least until further tests have been made.

The average loss from potato blight and rot in New York in 1904 was at least 60 bushels per acre. Most of this loss was due to late blight and the rot which follows it.

The practice of spraying potatoes for blight is on the increase in this State. Many potato growers are preparing to spray in 1905. Western New York and Long Island are taking the lead in this work.

Farmers are advised to hire their potato spraying done by some one who makes such work his business. In this way the expense of spraying can be reduced and the extra labor and bother of spraying avoided.

Judging from the results of the experiments thus far made, it appears that spraying for blight is an operation which no potato grower in New York can afford to neglect. Farmers are requested to make experiments and report the results to the Station. Directions for spraying are given on page 193.

INTRODUCTION.

During the season of 1904 the Station continued the ten year potato-spraying experiments begun in 1902. These experiments are designed to determine how much the yield of potatoes can be increased, on the average, by spraying with bordeaux mixture. The plan is to continue the experiments during ten consecutive seasons and take the average increase in yield as the index of the value of spraying potatoes in New York State. The experiments are to be conducted in two localities; namely, at Geneva and at Riverhead. Two methods of spraying are to be compared as to their efficiency; Some rows are sprayed every two weeks regularly while others are sprayed only three times during the season. At each place the area of the experiment field is to be three-

tenths of an acre each season. The rows sprayed every two weeks alternate with those sprayed only three times and with others not sprayed at all. For further details see Bulletin 221.

Supplementary to the above experiments, the Station has conducted a series of business experiments similar to those made in 1903.[1] Under direction of the Station, fourteen farmers in different parts of the State have carried on experiments designed to determine the net profit in spraying potatoes in different ways under ordinary farm conditions.

A third line of effort has been the collection of the results of numerous volunteer potato-spraying experiments made by farmers. Forty-one such experiments are reported in this bulletin. The most important feature of these experiments, as a whole, is the increase in yield due to spraying. However, nearly every one of them contains other points of interest.

SUMMARY OF RESULTS OBTAINED IN TEN-YEAR EXPERIMENTS IN 1902.[2]

TABLE I.—YIELD BY SERIES AT GENEVA IN 1902.

SERIES.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	lbs.
I	1, 4, 7 and 13	July 10, 23 and Aug. 12	317	41
II	2, 5, 8 and 14	June 25, July 10, 23, 30, Aug. 12, 26 and Sept. 10	342	36
III	3, 6, 9 and 15	Not sprayed	219	4

Gain due to spraying three times, 98½ bu. per acre.
Gain due to spraying seven times, 123½ bu. per acre.

TABLE II.—YIELD BY SERIES AT RIVERHEAD IN 1902.

SERIES.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	lbs.
I	2, 5, 8 and 11	May 26, June 20 and July 12	295	20
II	1, 4, 7 and 10	May 26, June 3, 20, 30, July 11, 23 and Aug. 5	312	35
III	3, 6, 9 and 12	Not sprayed	267	40

Gain due to spraying three times, 27⅔ bu. per acre.
Gain due to spraying seven times, 45 bu. per acre.

[1] For an account of the business experiments conducted in 1903 see Bulletin 241 of this Station, pp. 267–283.
[2] For details of the experiments in 1902 see Bulletin 221 of this Station.

SUMMARY OF RESULTS OBTAINED IN TEN-YEAR EXPERIMENTS IN 1903.[3]

TABLE III.—YIELD BY SERIES AT GENEVA IN 1903.

SERIES.	ROWS.	Dates of spraying.[4]	Yield per acre.	
			Bu.	*lbs.*
I	1, 4, 7, 10 and 13	July 14, 28 and Aug. 26	262	—
II	2, 5, 8, 11 and 14	July 7, 21, Aug. 7, 21 and Sept. 3	292	10
III	3, 6, 9, 12 and 15	Not sprayed	174	20

Gain due to spraying three times, 88 bu. per acre.
Gain due to spraying five times, 118 bu. per acre.

TABLE IV.—YIELD BY SERIES AT RIVERHEAD IN 1903.

SERIES.	ROWS.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I	1, 4, 7 and 10	June 5, July 22 and Aug. 7	246	45
11	2, 5, 8 and 11	June 5, 24, July 7, 22 and Aug. 7	263	10
III	3, 6, 9 and 12	Not sprayed	207	10

Gain due to spraying three times, 39½ bu. per acre.
Gain due to spraying five times 56 bu. per acre.

DETAILS OF TEN-YEAR EXPERIMENTS IN 1904.

FITTING, PLANTING, CULTIVATION, ETC.

At Geneva.—The plat of land used was adjacent to that used for the experiment in 1903 and of the same kind of soil; namely, a heavy clay loam with some gravel in it. In 1903 it grew corn. In the fall well rotted stable manure was applied, by means of a manure spreader, at the rate of twenty-four loads per acre and plowed under. The following spring the land was plowed again, on May 18. There having been plenty of rain the soil was moist, but in spite of thorough harrowing it was left lumpy and in poor condition for planting.

The rows were marked out three feet apart. Immediately before planting the furrows were opened with a plow. Fertilizer at the rate of 200 pounds[5] per acre (four pounds to each row) was scattered in the furrows by hand. Planting was done May

[3] For details of the experiments in 1903 see Bulletin 241 of this Station.
[4] The dates of spraying as given in Table IV on p. 263 of Bulletin 241 are incorrect.
[5] 100 pounds soluble bone (14–16 per ct. available phosphoric acid), 80 pounds dried blood and 20 pounds sulphate of potash.

25 and 26. The seed pieces were placed exactly 15 inches apart in the row. They were covered four inches deep by means of hoes.

The seed was of the variety Rural New Yorker No. 2, selected from the rows sprayed every two weeks in the experiment of 1903. On May 11 the seed tubers were given the formalin treatment for scab.[6] Twenty-four hours before planting they were cut into pieces weighing about one ounce each (11 bushels per acre) without regard to the number of eyes except that each piece bore at least one good eye. Although much care was taken to reject all tubers showing signs of rot, undoubtedly an occasional diseased piece was planted.

During the season the field was harrowed once (as the plants were coming through), hoed once and cultivated four times. The plants were not hilled at all.

At Riverhead.—The previous crop was cauliflower. The land was plowed 6 to 8 inches deep April 20. After treatment with formalin for scab, planting was done by hand on May 4 with pieces of hen's egg size placed 15 inches apart in the row and the rows three feet apart. The seed used was of the variety Carman No. 1, selected from the sprayed rows in the experiment of 1902.

The trenches for planting were opened with a shovel plow. Home mixed fertilizer[7] costing $25 per ton was sown in these trenches by hand at the rate of 1,000 pounds per acre, or 25 pounds per row. Before planting, the fertilizer was mixed with the soil by running a cultivator through the trenches. The seed was covered to a depth of about four inches by means of the shovel plow used in opening the trenches.

The cultivation consisted of two harrowings (one before the plants were visible and the other as they were breaking through), six cultivations with a horse cultivator (once before and five times after the plants were up), and one hoeing. In the last cultivation the plants were well ridged. On August 8, large weeds in the rows were pulled and three weeks later a hoe was used to remove the few remaining weeds in the rows so that

[6] Tubers soaked two hours in a solution containing one pint of formalin in 30 gallons of water.

[7] Formula: Nitrogen, 3.8 per ct.; phosphoric acid, 10.25 per ct.; and potash, 4.35 per ct.

when the potatoes were dug, September 9, the field was entirely free from weeds. The soil was of the same character as that used in 1902 and 1903, namely, a well-drained sandy loam, containing some gravel.

PREPARATION AND APPLICATION OF THE BORDEAUX MIXTURE.

Both at Geneva and at Riverhead the bordeaux mixture used was approximately of the 1–to–8 formula, the same as in the experiments of 1902 and 1903.[8] It was applied with a knapsack sprayer and very thoroughly. (See Plate I.) In the later sprayings, after the vines became large, the rows were gone over twice at each spraying, the operator going out on one side and back on the other. This was done to insure thoroughness and uniformity of application. Some difficulty was experienced in spraying the rows of Series I and II without getting some of the spray on the unsprayed rows of Series III. This was avoided to a considerable extent by lifting the vines of the unsprayed rows out of the way; but with a side wind blowing it was impossible to prevent entirely the drifting of spray onto the unsprayed rows.

In the later sprayings the bordeaux was applied at the rate of about 200 gallons per acre at Geneva and 120 gallons per acre at Riverhead.

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[8] At the Experiment Station at Geneva there is kept on hand a stock solution of copper sulphate prepared by dissolving 100 pounds of copper sulphate in 50 gallons of water. Thus, each gallon of stock solution contains two pounds of copper sulphate. Likewise, 50 to 100 pounds of lime is slaked and kept in stock solution ready for use in a large wooden vat. In the preparation of bordeaux mixture for spraying potatoes three gallons of the stock solution of copper sulphate (containing six pounds copper sulphate) is poured into a 50-gallon barrel half full of water. Into this, dilute milk of lime from the lime vat is then poured through a strainer until the mixture will "stand the test." The mixture is "tested" by dropping into it a few drops of a solution of yellow prussiate of potash. If more lime is required the "test" solution turns reddish brown as soon as it comes in contact with the bordeaux mixture. In such case, more milk of lime is added until the brown color ceases to appear when the "test" is made. When this stage is reached it is our custom to add yet a little more of the milk of lime to make sure that there is plenty. An excess of lime does no harm. The mixture should always be thoroughly stirred before testing.

The bordeaux mixture used in the experiment at Riverhead is prepared in essentially the same way except that the stock solution of copper sulphate used is what is called a saturated solution. This is prepared by adding to water as much copper sulphate as it will dissolve. The advantages of using a saturated stock solution are: (1) It saves the bother of weighing; (2) there is no danger of the strength being increased by evaporation—it is always the same, namely, three pounds per gallon.

For further details of the preparation of bordeaux mixture see Bulletin 243, pp. 319–324.

DATES OF SPRAYING.

At Geneva: Series I.—The rows of this series, 1, 4, 7, 10 and 13, were sprayed three times with bordeaux mixture—July 13, 27 and August 15. At the time of the first spraying bugs[8a] had not yet done appreciable damage, but they were becoming very numerous and it was believed that treatment could not be longer delayed with safety. To poison the bugs paris green was added to the bordeaux at the rate of one pound to 50 gallons. At this time the plants were 12 to 14 inches high and growing rapidly.

Although the first spraying was effective in ridding the plants of bugs a second spraying, on July 27, was necessitated by the appearance of a second crop of them. This time paris green was used at the rate of one-half pound to 50 gallons of bordeaux. The treatment was effective and there was no further trouble with bugs. Probably, this second spraying was very useful in preventing the early attack of blight. Traces of blight had been found on the unsprayed rows the day before.

The third and last spraying on this series was made August 15 with bordeaux alone. Spraying could not be longer delayed because blight was already well established on the unsprayed rows and even on the rows of this series there was an occasional leaf affected. Moreover, the plants were almost entirely unprotected. All traces of the previous spraying had disappeared, the bordeaux having been washed off by heavy rains and there was also a large amount of unprotected new growth.

Series II.—This series consisted of rows 2, 5, 8, 11 and 14. The plants were sprayed five times—July 8, 22, August 1, 15 and 29. At the time of the first spraying the plants were 6 to 8 inches high. On this series it was thought advisable to use poison three times.[9] In the first two sprayings it was needed because of bugs and in the third spraying it was used because an outbreak of flea-beetles was expected. The principal part of the first crop of bugs appeared about July 12. As the first application of poison was made July 8 many of the bugs escaped it with

[8a] Throughout this bulletin the word "bugs" refers to the Colorado potato beetle, *Doryphora decemlineata*.

[9] In the first spraying, arsenite of soda—one pint of stock solution to 50 gallons; in the second and third sprayings, paris green—one-half pound to 50 gallons.

the result that slight damage was done by them before they were killed by the second application of poison, on July 22.

The interval between the second and third sprayings was shortened to ten days. This was thought necessary because much of the bordeaux had been washed off by rain, the weather conditions were highly favorable to blight and there were indications of an attack of flea-beetles.

On September 12, two weeks after the fifth spraying, the plants of this series still possessed most of their foliage, enough to warrant a sixth spraying but for the fact that they were still so thoroughly coated with bordeaux from the last spraying as to make another application quite superfluous.

Series III.—Series III consisted of rows 3, 6, 9, 12 and 15. They were not sprayed at all with bordeaux mixture but were treated twice (July 13 and 26) with paris green in lime water, one pound to fifty gallons in the first spraying and one-half pound to fifty gallons in the second. It was applied by means of a knapsack sprayer. In both sprayings the bugs were practically all killed so that the rows of this series were not damaged by bugs.

At Riverhead: Series I.—This series consisted of four rows, Nos. 1, 4, 7 and 10, which were sprayed with bordeaux mixture three times; namely, on June 14, July 21 and August 9. Poison, arsenite of soda,[10] was used in the first spraying at the rate of one quart of the stock solution to 50 gallons of bordeaux, and in the second spraying at the rate of two quarts to 50 gallons. The third spraying was made with bordeaux alone.

Series II.—This series consisted of four rows—Nos. 2, 5, 8 and 11. They were sprayed with bordeaux six times; namely, on June 14, 27, July 11, 26, August 9 and 22. As on Series I, poison was used with the bordeaux in the first two sprayings; but the last four sprayings were made with bordeaux alone.

Series III.—Series III also consisted of four rows—Nos. 3, 6, 9 and 12. The rows of this series were not sprayed at all with bordeaux, but when bugs appeared in destructive numbers (July 6) they were poisoned by dusting the plants with arsenate of lead. The treatment was effective and there was no further trouble with bugs, but in some places the foliage was slightly burned by the poison.

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[10] For the preparation of arsenite of soda see p. 190.

Plate I.—Spraying with a Knapsack Sprayer in the Ten-Year Experiment at Geneva.

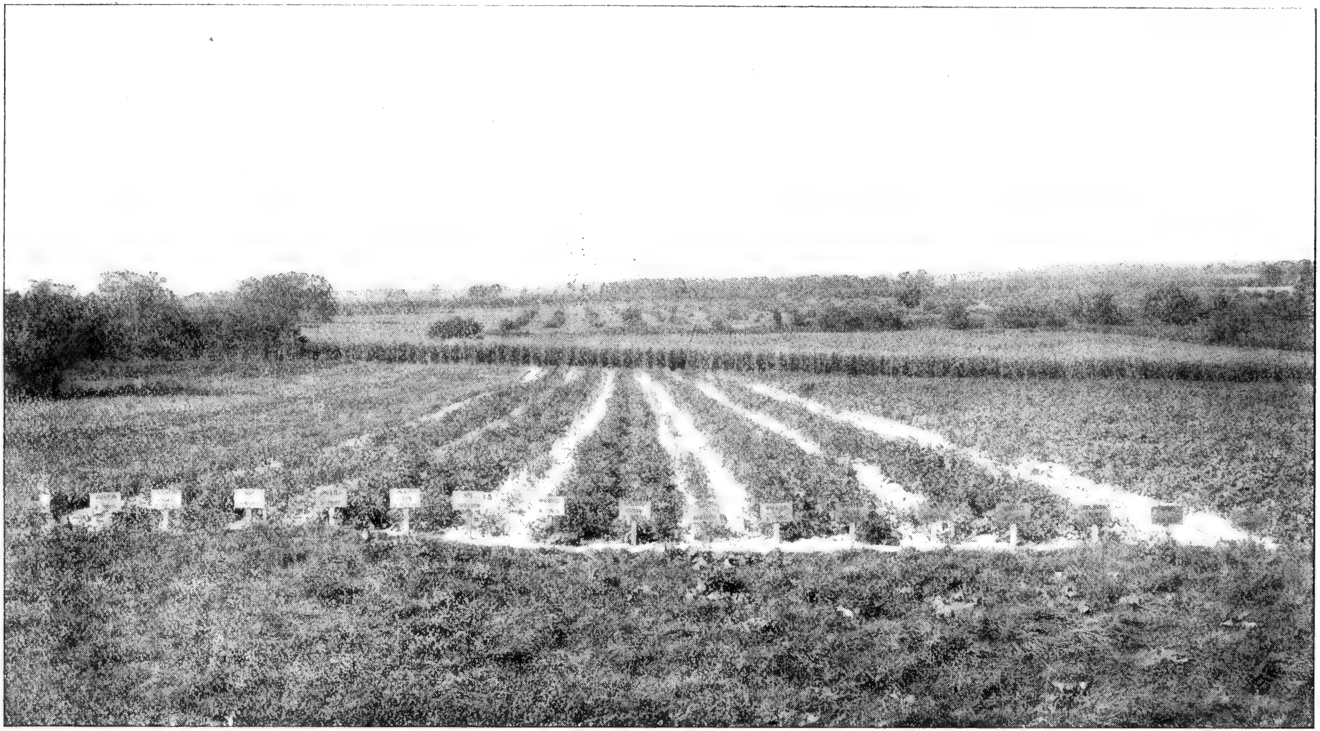

PLATE II.—GENERAL VIEW OF TEN-YEAR EXPERIMENT AT GENEVA.

Photographed Sept 16. Unsprayed rows entirely dead; three-fourths of foliage on sprayed rows still green.

PLATE III.—ROWS 8, 9 AND 10 IN TEN-YEAR EXPERIMENT AT GENEVA.
Photographed Sept. 17.

Per acre: 380 bu. 161 bu. 350½ bu.

PLATE IV.—ROWS 8, 9 AND 10 IN TEN-YEAR EXPERIMENT AT GENEVA.

Viewed by committee of the N. Y. State Fruit Growers' Association. See p. 100

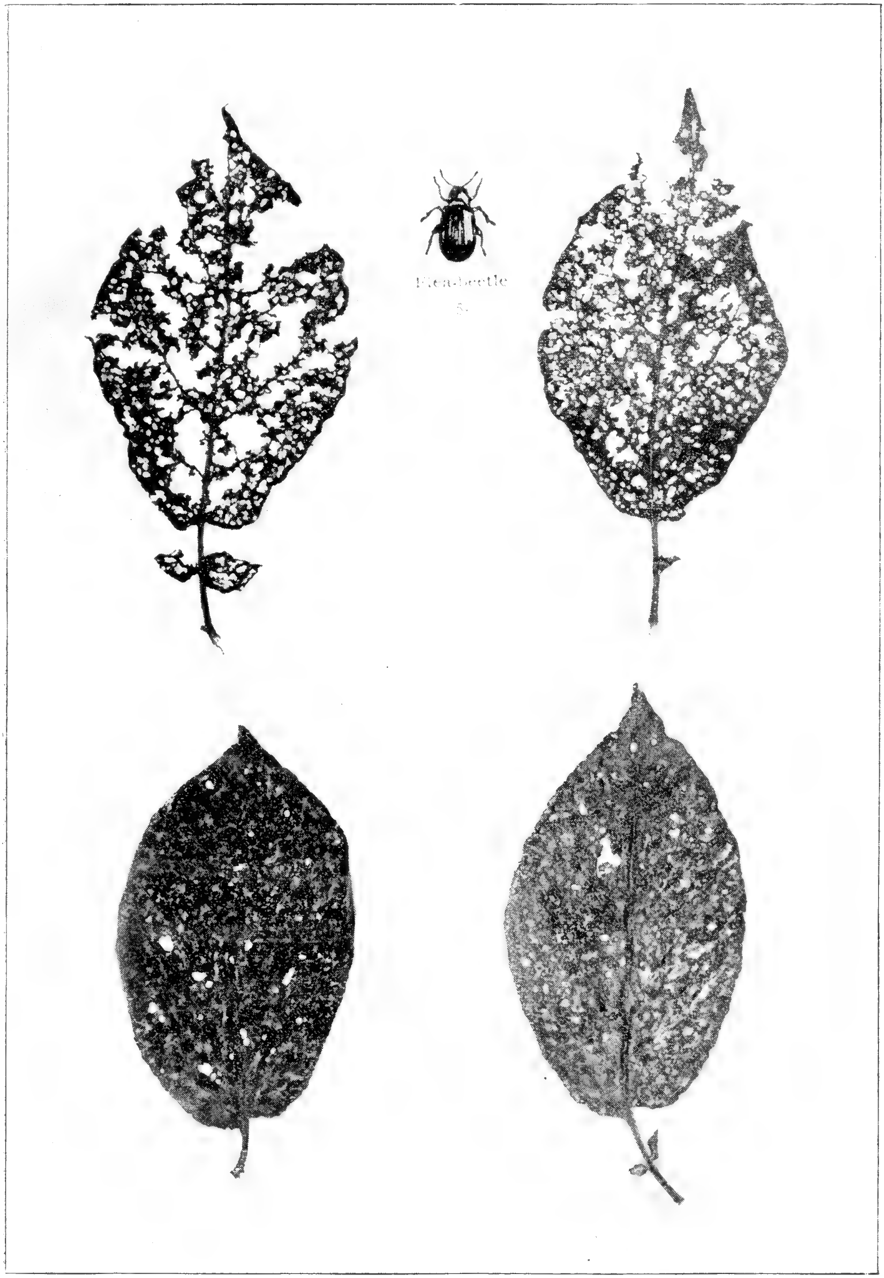

PLATE V.—THE FLEA-BEETLE AND ITS WORK: POTATO LEAFLETS SHOWING AVERAGE CONDITION OF FOLIAGE ON ADJACENT SPRAYED (LOWER) AND UNSPRAYED (UPPER) ROWS IN TEN-YEAR EXPERIMENT AT RIVERHEAD.

PLATE VI.--COOKING TEST OF SPRAYED AND UNSPRAYED POTATOES: TUBERS FROM ADJACENT ROWS IN TEN-YEAR EXPERIMENT AT GENEVA.

Sprayed potatoes were much more mealy.

FIG. 1.—SPRAYING IN THE GAINESVILLE EXPERIMENT.

FIG. 2.—SPRAYING IN THE SPENCERPORT EXPERIMENT.

PLATE VII.

FIG. 1.—SPRAYING IN THE WEST HENRIETTA EXPERIMENT.

FIG. 2.—THE WEST HENRIETTA EXPERIMENT.

Photographed Sept. 22. Spraying increased the yield 130 bushels per acre.

PLATE VIII.

THE RESULTS OF THE TEN-YEAR EXPERIMENTS.

AS INDICATED BY THE CONDITION OF THE FOLIAGE.

At Geneva.—The only damage done by potato bugs was a slight injury to the plants in Series II between the first and second sprayings. Flea-beetles were almost entirely absent. About August 1 a few appeared but the damage done by them was inappreciable. There was no early blight, *Alternaria solani.* On July 19 many of the plants in all three series showed a few leaves with dead, brown tips. This was attributed to sunscald brought about by several bright, hot days following a period of cloudy, wet weather. No material damage was done. Twice during the season the ground became hard and dry and more rain would probably have been beneficial, but it can scarcely be said that the plants were at any time injured by drought.

The only important disease in the experiment field last season was late blight caused by the parasitic fungus, *Phytophthora infestans;* and the remarkable difference in yield between sprayed and unsprayed rows is to be attributed almost entirely to the greater ravages of blight and rot on the unsprayed rows.

The first discovery of late blight in the experiment field was made July 25. On that date a half hour's search revealed nine affected leaves—seven on unsprayed plants and two on sprayed. During several days following there were frequent showers and the disease soon became thoroughly established.

By August 9 the unsprayed rows (Series III) were already considerably blighted. In several places many lower leaves were dead and dry giving the plants the "trimmed-up" appearance characteristic of plants affected with late blight. Four days later one-third of the foliage on the unsprayed rows was ruined by blight and on August 29 it was estimated that, on an average, fully three-fourths of the foliage was dead, leaving the stalks with only tufts of green leaves at their tips. At the same time the plants on the sprayed rows (Series I and II) were in almost full foliage, the leaves being green and perfect clear down to the ground. There seemed to be no difference between rows sprayed three times (Series I) and rows sprayed every two weeks (Series II). On both series there were traces of blight all along the rows, but not enough to affect growth materially.

On September 10 the following notes were made:

Row 1. Sprayed three times. Five hills entirely dead and one nearly dead; all others in nearly full foliage.

Row 2. Sprayed every two weeks. One hill nearly dead; all others in nearly full foliage.

Row 3. Unsprayed.	Hills entirely dead with stems dry....	102
	Hills with leaves all dead but stems succulent.	23
	Hills with some green leaves..........	102
	Total.	227

Row 7. Sprayed three times. Seven hills entirely dead and two more nearly dead; all others in nearly full foliage.

Row 8. Sprayed every two weeks. Six hills entirely dead and one nearly dead; all others in nearly full foliage.

Row 9. Unsprayed.	Hills entirely dead with stems dry....	125
	Hills with leaves all dead but stems still succulent.	24
	Hills with some green leaves.........	80
	Total.	229

The sprayed rows of both series beginning to decline. Rows sprayed every two weeks slightly superior to those sprayed only three times.

On September 12 the unsprayed rows were pronounced dead. A few of the plants still had small tufts of green leaves but there was certainly no material growth of tubers after this date. The sprayed rows, on the contrary, continued in good foliage and must have made considerable growth of tubers for at least two weeks longer. On the night of September 22 there was a frost which killed potatoes over the greater part of the State, but owing to their elevated situation the experiment potatoes were only slightly injured.

After September 26 the sprayed rows deteriorated rapidly, but as late as October 5 the rows sprayed every two weeks still presented a continuous strip of green foliage clear across the field. They were finally killed by frost on the night of October 6 after having lived fully 25 days longer than those unsprayed. How-

ever, the actual difference in growth must have been considerably greater than this since the unsprayed plants could have made but little growth for two weeks before they were all pronounced dead.

All through September the contrast in appearance between the sprayed and unsprayed rows was very striking, being greatest about September 16 when a photograph of the field was taken. (See Plate II[11].) Since the experiment field was located beside a much traveled highway leading into Geneva, many farmers passing the field in going to and from the city watched the progress of the experiment with much interest. Several said that they could not have believed that spraying could make such a difference had they not seen it. But great as was the difference in growth, the difference in yield was even more remarkable.

At Riverhead.—As previously stated, bugs were kept under control on all the plats and so had nothing to do with the differences in the appearance of the foliage. Flea-beetles, on the contrary, were a very important factor. They were quite plentiful the last of May and about July 17 they again appeared in such numbers that the unsprayed rows were soon severely injured. On July 21, there was a strong contrast in appearance between sprayed and unsprayed rows and by August 9 the unsprayed rows (Series III) were practically ruined. Even the rows of Series I (at that time sprayed twice) were severely injured, but on Series II (already sprayed three times) the damage was slight. (See Plate V.)

This was one of the most severe attacks of flea-beetles the writers have ever seen.

Late blight, *Phytophthora infestans*, first appeared on the unsprayed rows August 10 and quickly killed the remnants of foliage left by the flea-beetles. Early blight, too, caused slight injury on the unsprayed rows. But the increase in yield on the sprayed rows in this experiment is chiefly due to the fact that the bordeaux gave partial protection against the ravages of flea-beetles.

As nearly as could be determined, the dates marking the death of the plants on the different series are as follows: Series I, August 27; Series II, September 1; and Series III, August 14.

[11] Much difficulty has been experienced in getting photographs to show properly the contrast in appearance between blighted and unblighted rows of potatoes in our spraying experiments. In Plates II, III and XV this difficulty has been partially overcome by sifting air-slaked lime over the bare ground on the unsprayed rows.

AS SHOWN BY THE YIELD.

At Geneva.—The potatoes were dug by hand October 18 and 19. At this time the plants on the unsprayed rows had been dead over a month and were thoroughly dry. Those on the sprayed rows had been killed by frost twelve days before and most of the stems were already dry.

Some remarkable results being anticipated it was thought desirable to have witnesses present at the digging. Mr. T. B. Wilson of Halls Corners, President of the New York State Fruit Growers' Association, was requested to name some one to act with him as a committee to witness the digging. Mr. Wilson kindly consented and named as the other member of the committee, Mr. C. K. Scoon, a fruit grower of Geneva. These two gentlemen met at the Station on the afternoon of October 18. Because of lack of time it was not feasible for them to remain until all 15 rows were dug. Accordingly, three rows, Nos. 8, 9 and 10, about the middle of the field, were selected for the test. These rows they saw dug, weighed, and the length measured. As the tubers lay on the ground after digging they were photographed. (See Plate IV.) Plate III shows the same rows as they appeared on September 17. The yields are given in Table V.

Throughout the experiment the product of each row was sorted into three grades—marketable, rotten and culls. All sound tubers larger than a hen's egg were graded as marketable. The sorting was all done by the writers and as uniformly as possible.

TABLE V.—YIELDS IN THE EXPERIMENT AT GENEVA,

SECTION.	Row.	Treatment.	Yield per Row.[12]		Yield per Acre.			
			Marketable.	Culls.	Marketable.		Culls.	
			Lbs.	*Lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
A.	1	Sprayed 3 times	412	16	343	20	13	20
	2	Sprayed 5 times	471	15	392	30	12	30
	3	Unsprayed	169	42	140	50	35	—
B.	4	Sprayed 3 times	438	17	365	—	14	10
	5	Sprayed 5 times	475	18	395	50	15	—
	6	Unsprayed	185½	38	154	35	31	40
C.	7	Sprayed 3 times	407	24	339	10	20	—
	8	Sprayed 5 times	456	13	380	—	10	50
	9	Unsprayed	193	46	160	50	38	20
D.	10	Sprayed 3 times	420½	19½	350	25	16	15
	11	Sprayed 5 times	486	20	405	—	16	40
	12	Unsprayed	184½	34	153	45	28	20
E.	13	Sprayed 3 times	389½	15½	324	35	12	55
	14	Sprayed 5 times	432	11	360	—	9	10
	15	Unsprayed	188½	34	157	5	28	20

[12]Rows 290.4 feet long by three feet wide making the area of each row exactly one-fiftieth of an acre. Concerning the loss from rot, see page 102.

Comments on the table.—A study of the above table reveals the following: (1) In each of the five sections the five-sprayed row yielded more than the three-sprayed row, the difference varying from 31 to 55 bushels per acre.

(2) In each section the sprayed rows yielded more than twice as much as the unsprayed row. The five-sprayed row outyielded the adjacent unsprayed row by 203 to 252 bushels per acre.

(3) In different sections the yields of rows treated in the same way varied considerably. The yield of the unsprayed rows varied from 141 to 161 bushels per acre; on the rows sprayed three times it varied from 324 to 365 bushels per acre; and on the rows sprayed five times from 360 to 405 bushels. When it is considered that the rows of each series were treated in all respects in the same way as nearly as possible it is plain that these variations in yield must have been due to slight variations in the soil in differ-parts of the field, although it is not known why such soil variations should exist. They were not evident to the eye. There were neither dead furrows nor back furrows in the field and the soil appeared uniform. It is obvious that confidence should be placed only in averages.

(4) Another interesting fact brought out in the table is the smaller quantity of culls on the sprayed rows in each section. On the average there were less than half as many culls on the sprayed rows as there were on the unsprayed. Owing to the premature death of the unsprayed plants many tubers on those rows did not finish their growth.

Yield by series.—The five rows sprayed three times constitute Series I and the average yield of these five rows makes the yield of Series I. The yields given for Series II and III have been computed in the same manner. The yield by series is shown in the following table:

TABLE VI.—YIELD BY SERIES AT GENEVA.

SERIES.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I	1, 4, 7, 10 and 13	July 13, 27 and Aug. 15	344	30
II	2, 5, 8, 11 and 14	July 8, 22, Aug. 1, 15 and 29	386	40
III	3, 6, 9, 12 and 15	Unsprayed	153	25

Increase in yield due to spraying three times, 191 *bu. per acre.*
Increase in yield due to spraying five times, 233 *bu. per acre.*

As in previous years, the difference in yield between Series I and II was greater than would be expected, judging from the difference in the appearance of the foliage. Only at the close of the season was there any apparent difference between the rows sprayed three times and those sprayed five times. The three-sprayed rows were so little injured by blight that the average observer would not have noticed it except by comparison with the adjacent five-sprayed rows. Yet the difference in yield was at the rate of 42 bu. per acre.

Loss from rot.—There was a little rot on both sprayed and unsprayed rows. It was impossible to estimate the amount accurately because many of the affected tubers were in an advanced stage of decay. Although there seems to have been somewhat more rot on the unsprayed rows than on the sprayed the casual observer might have thought the reverse true for the reason that on the unsprayed rows many affected tubers had decayed almost completely and nearly disappeared, while on the sprayed rows the decay was less advanced and all of the affected tubers still in evidence.[13] The very large yield on the sprayed rows is evidence that there was not much loss from rot on those rows. The difference in yield between sprayed and unsprayed rows was due chiefly to the longer growth of the sprayed plants and only in small degree to the prevention of rot.

[13] At digging time all tubers showing the least indication of rot were carefully sorted out. Nevertheless, after three months in storage there was a considerable amount of rot among the sprayed tubers but none among the unsprayed. On three rows the amount of this rot was determined and found to be as follows:

Row 8, sprayed 5 times, 30¼ pounds rotten = 25 bushels 12 pounds per acre.

Row 9, unsprayed, none rotten.

Row 10, sprayed three times, 40¼ pounds rotten = 34 bushels 12 pounds per acre.

This does not mean that spraying causes potatoes to rot in storage. Usually, sprayed potatoes keep better than unsprayed ones. Our explanation of the matter is that the sprayed potatoes were dug too soon after the tops died.

At the time of digging, the unsprayed rows were long since dead and about done rotting while the sprayed rows were not. Hence, it was less easy to detect the rotten tubers on the sprayed rows and some slightly affected ones were accidently passed as marketable. It is also likely that in digging, the tubers on the sprayed rows were brought into contact with live blight spores on the foliage and infected in that way. Had the digging been delayed a few days these spores would have died when the tops became dry and the tubers could then have been dug with safety. If blighted potatoes are to be stored they should not be dug until the tops are thoroughly dry. (See page 192.)

At Riverhead.—The potatoes were dug on September 9 and sorted into two grades, marketable tubers and culls, in the same manner as at Geneva.

TABLE VII.—YIELDS IN THE EXPERIMENT AT RIVERHEAD.

SECTION.	Row.	Treatment.	YIELD PER ROW.				YIELD PER ACRE.			
			Marketable.		Culls.		Marketable.		Culls.	
			Lbs.	*oz.*	*Lbs.*	*oz.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
A............	1	Sprayed 3 times.....	409	—	58	—	272	40	38	40
	2	Sprayed 6 times.....	404	—	62	4	269	20	41	30
	3	Unsprayed..........	281	—	86	12	187	20	57	50
B............	4	Sprayed 3 times.....	372	10	48	14	248	25	32	35
	5	Sprayed 6 times.....	424	12	52	—	283	10	34	40
	6	Unsprayed..........	305	2	80	—	203	25	53	20
C............	7	Sprayed 3 times.....	386	—	52	8	257	20	35	—
	8	Sprayed 6 times.....	476	13	57	7	317	52	38	17
	9	Unsprayed..........	302	6	103	8	201	35	69	—
D............	10	Sprayed 3 times.....	380	3	29	—	253	27	19	20
	11	Sprayed 6 times.....	481	—	57	—	320	40	38	—
	12	Unsprayed..........	320	1	98	4	213	22	65	30

Comments on the table.—As in 1902 and 1903 the difference in yield between the sprayed and unsprayed rows was much smaller at Riverhead than at Geneva. This is largely due to difference in soil rather than to locality. In the experiment field at Riverhead the soil is very sandy and dry and during the past three years blight has been less destructive than in most other fields in the locality.

In all four sections each of the sprayed rows yielded more than the unsprayed row, and, with one exception, Section A, the row sprayed six times outyielded the row sprayed three times. Why Row 1 (sprayed three times) yielded three bushels per acre more than Row 2 (sprayed six times) is not known.

Yield by series.—The yield by series is shown in the following table:

TABLE VIII.—YIELD BY SERIES AT RIVERHEAD.

SERIES.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I............	1, 4, 7 and 10.......	June 14, July 21 and Aug. 9.......	257	58
II............	2, 5, 8 and 11.......	June 14, 27, July 11, 26, Aug. 9 and 22..........................	297	45
III............	3, 6, 9 and 12.......	Not sprayed......................	201	25

Increase in yield due to spraying three times, $56\frac{1}{2}$ bu. per acre.
Increase in yield due to spraying six times, $96\frac{1}{3}$ bu. per acre.

Loss from rot.—As nearly as could be estimated, the loss from rot was three per ct. on Series I, one per ct. on Series II and six per ct. on Series III. Even on the unsprayed rows the loss from rot was not nearly as great as in most other fields in the neighborhood. Most of the increase in yield on the sprayed rows was due to the prolonged growth of the plants and consequent larger size of the tubers.

AS SHOWN BY CHEMICAL ANALYSIS.

In the experiment at Geneva in 1902, fifty consecutive hills from a row sprayed seven times and the same number of hills from an adjacent unsprayed row were analyzed in order to determine whether spraying had affected the chemical composition of the tubers. It was found that the sprayed potatoes contained a larger percentage of dry matter which consisted mostly of starch. (See Bulletin 221, page 254.)

Similar analyses made in 1903 showed very slight difference between sprayed and unsprayed tubers. The percentage of dry matter was only .05 per ct. greater and of starch .02 per ct. greater in the sprayed than in the unsprayed potatoes. (See Bulletin 241, page 266.)

In 1904 analyses were again made. Fifty consecutive hills from a row sprayed five times (Row 5) were compared with fifty hills from an adjacent unsprayed row (Row 6). The chemical work was done by Mr. F. D. Fuller, Assistant Chemist, whose report is shown in the following table:

TABLE IX.—CHARACTER AND COMPOSITION OF SPRAYED AND UNSPRAYED POTATOES.

YIELD AND SIZE OF TUBERS.

TREATMENT.	NUMBER OF TUBERS IN 50 HILLS			Tubers in one hill.	Total weight of tubers.	Average weight of tubers.
	Merchantable.	Unmerchantable.	Total.			
					Lbs.	*Oz.*
Sprayed potatoes...........	223	42	265	5.30	104.7	6.36
Unsprayed potatoes.........	151	70	221	4.42	47.8	3.42

COMPOSITION OF TUBERS.

Lab. No.	TREATMENT.	Water.	Dry matter.	Ash.	Protein.	Nitrogen-free compounds.	Starch.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1735	Sprayed potatoes......	79.44	20.56	1.20	1.67	17.69	14.07
1736	Unsprayed potatoes....	80.67	19.33	1.22	2.06	16.05	12.61

From an examination of the table it will be seen that the results in 1904 agree with those obtained in 1902 in showing the sprayed tubers to contain a considerably higher percentage of dry matter and also of starch.

EFFECT ON COOKING QUALITY.

Several cooking tests were made to determine whether there was any difference in quality between the sprayed and unsprayed potatoes. In one of these tests 21 tubers from a row sprayed five times were compared with the same number of tubers from an adjacent unsprayed row. Each lot contained tubers of small, medium and large size. Some were boiled and others baked. It was the unanimous opinion of the five persons who participated in this test that the sprayed potatoes were much more mealy and of better flavor than the unsprayed. The difference was more pronounced when the potatoes were boiled than when baked.

In another test four sprayed and four unsprayed tubers of approximately the same weight (eight ounces each) were cut crosswise, without peeling, into halves. One half of each tuber was used in the test and the other half rejected. The total weight of the four sprayed pieces was 16 ounces and of the four unsprayed pieces the same. The two lots were boiled in the same vessel for 25 minutes. Again, the difference in mealiness was strikingly in favor of the sprayed pieces. (See Plate VI.)

In some of the other tests the difference was less marked, but in all cases great enough to leave no doubt that spraying had materially increased the mealiness. In fact, some of the larger sprayed tubers were so mealy that they boiled to pieces more than is desirable.

These cooking tests were made about the middle of January.

FARMERS' BUSINESS EXPERIMENTS.

OBJECT OF THE EXPERIMENTS.

Many farmers question the reliability of the results obtained in experiments like the Station ten-year experiments described in this bulletin. They doubt that such results can be obtained in ordinary farm practice. The objections[14] to the experiments

[14] See Bulletin 221 of this Station, pp. 257–261, for a discussion of these objections.

are: (1) They are on too small a scale (three-tenths of an acre); (2) the spraying is done more thoroughly than farmers would do it; (3) it is impossible to determine accurately the expense of the spraying; (4) the idea is prevalent that the Station potatoes are given extra good care in order that large yields may be obtained.

To satisfy this demand for experiments of a more practical kind the writers decided to conduct a series of farmers' business experiments so managed as to show the actual profit in spraying potatoes under ordinary farm conditions. This work was commenced in 1903 with six experiments.[15] The results proved of such general interest that it was thought best to increase the number of experiments in 1904. It now seems probable that several of these business experiments will be made each season during the remaining seven years in which the potato spraying experiments are to be continued.

METHODS.

In the spring of 1904 the Station arranged with fourteen farmers in different parts of the State to keep an account of their spraying operations on potatoes. An accurate record was kept of all the expense of the spraying including labor, chemicals and wear of machinery. In each experiment three to seven rows were left unsprayed except that they were treated with poison to protect them from bugs. The spraying and all work connected therewith was done by the farmers themselves and in such manner as they thought best although in some cases the Station offered advice.

In the fall, the tubers on one or more of the unsprayed rows were carefully weighed. The same was done with one or more of the sprayed rows on either side. In this manner it was determined how much the yield had been increased by spraying. In all cases a representative of the Station was present when the test rows were dug and assisted with the weighing. The length and width of the rows were carefully measured, the Station representative assisting with this also. Accordingly, we can vouch for the accuracy of the yields reported. During the season the experiments in Western New York were visited twice,

[15] Details of these experiments were published in Bulletin 241 of this Station, pp. 267–282.

those in the northern part of the State once and those on Long Island twice, for the purpose of taking notes.

As far as possible the fields selected for experiment were located on a public road where the results of the experiment could be seen by passersby. The size of the experiment fields varied from two and two-thirds acres to 31 acres, the total acreage of the fourteen experiments being 180 acres. In one experiment the bordeaux mixture was applied with a five-gallon compressed air sprayer. In the others, horse sprayers of several different kinds were used.

THE GAINESVILLE EXPERIMENT.

This experiment was made by Brainerd & Beaumont, Gainesville, Wyoming County. Twenty-six acres of potatoes, all in one lot, were sprayed four times at a total expense of $3.19 per acre and the yield was thereby increased by 74 2-3 bushels per acre, worth $32.11. The net profit on the operation was at the rate of $28.92 per acre or $751.92 on the field of 26 acres.

The spraying was done with an old style "Aroostook" power sprayer manufactured by the Field Force Pump Co., Elmira, N. Y. (See Plate VII, fig. 1.) This sprayer covers five rows at each passage with one nozzle per row, applying the bordeaux at the rate of about 50 gallons per acre. Two horses are required to haul it. The pumping is done with power obtained from the wheels. The dates[16] of spraying were as follows:—*First*, July 21 and 22; *second*, July 29 and 30; *third*, August 15 and 17; *fourth*, August 23 and 24. To control bugs arsenite of soda[17] was added to the bordeaux in the first three sprayings at the rate of four quarts of stock solution to 50 gallons.

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[16] The dates given are those on which the test rows were sprayed. On July 8 and 9 eleven acres of the earlier-planted portion of the field were sprayed. In the spraying of August 23 and 24 only 19 acres were sprayed, including the 15 acres of the later-planted portion of the field and four acres of the earlier planted. Thus the entire field was sprayed four times and four acres had five sprayings; but the test rows were sprayed only four times.

[17] For the preparation of arsenite of soda see page 190. Brainerd & Beaumont used four quarts of the stock solution of arsenite of soda in 50 gallons of bordeaux and applied this quantity on an acre. This is equivalent to the application of two pounds of paris green per acre which we believe is more than is usually required. On the unsprayed rows the poison was applied at the same rate, using it with lime water instead of with bordeaux. So heavy an application with lime water is dangerous, but Brainerd & Beaumont inform us that very slight injury occurred in their experiment. They estimate the cost of the arsenite of soda stock solution, including expense of preparation, at ten cents per gallon, making it one-third as expensive as paris green at fifteen cents per pound.

The potatoes were of two varieties mixed—Carman No. 3 and Sir Walter Raleigh. Eleven acres were planted May 25 to 28 and the remaining fifteen acres June 6 to 11. The soil was a gravelly loam. Five rows 1,032 feet long were left unsprayed. These rows were in the later-planted portion of the field and a public highway ran by them at the north end. They were kept free from bugs by three applications of arsenite of soda in lime water, on July 22, 30 and August 17.

On August 17 the field was examined by one of the writers. The sprayed rows were in perfect foliage with no signs of blight, but on the unsprayed rows traces of late blight, *Phytophthora infestans,* were found. There was no evidence of injury from bugs on either the sprayed or unsprayed vines. The sprayed plants appeared somewhat larger than the unsprayed.

During this visit we had the opportunity, through the kindness of Mr. Brainerd, of examining a large number of potato fields in the vicinity of Gainesville. Several of these fields had been sprayed and were in good condition; but in every unsprayed field examined more or less blight was found. In the majority of cases no damage was done as yet, but in a few fields the disease was already well advanced and one field of five acres on low ground was entirely dead and the tubers rotting.

On August 23 Brainerd & Beaumont reported that the five unsprayed rows were quite badly blighted toward the north end next the road. The sprayed plants in the same part of the field were perfect. However, the contrast was not yet sufficiently marked to be noticed by one passing along the road. All unsprayed fields were becoming badly blighted.

On September 1 we personally examined the field a second time. Next the road the contrast in appearance between sprayed and unsprayed rows was now very marked. For a distance of about ten rods back from the road the unsprayed rows had lost from one-half to two-thirds of their foliage while the sprayed plants on both sides were nearly perfect with only an occasional leaf affected. Throughout the remainder of the unsprayed rows there was some blighted foliage all along but not enough to materially affect the growth of the plants. The unsprayed rows had not been in the least injured by bugs.

At this date four sprayings had been made, the last one on August 23 and 24. We advised a fifth application at once but the owners thought it would not pay and did not do it. Subsequently, Mr. Brainerd expressed the opinion that a fifth spraying would have been highly profitable.

On the night of September 21 the plants were killed by frost. Brainerd & Beaumont report that the five unsprayed rows were entirely dried up next the road although in much better condition farther south. The sprayed rows on one side had lost about three-fourths of their foliage and those on the other side about one-fourth. At a little distance all of the sprayed rows looked quite green. No doubt the yield would have been considerably greater had not the plants been killed by frost.[18] At the end next the road the sprayed plants lived about 18 days longer than the unsprayed.

The test rows were dug with a potato digger on October 13. The yields were as follows:

Second sprayed row on the west, 856 pounds marketable tubers.

Second sprayed row on the east, 808 pounds marketable tubers.

Average of two sprayed rows, 832 pounds marketable tubers.

Middle unsprayed row, 540 pounds marketable tubers.

Number of rows required to make an acre, 15.35.

Yield, sprayed, 212 bu. 51 lbs. marketable tubers per acre.

Yield, unsprayed, 138 bu. 9 lbs. marketable tubers per acre.

Gain, 74 bu. 42 lbs. marketable tubers per acre.

The yield of unmarketable tubers or culls was as follows:

Second sprayed row on the west, 97 pounds.

Second sprayed row on the east, 110 pounds.

Average of two sprayed rows, 103½ pounds or 26½ bushels per acre.

Middle unsprayed row, 84 pounds or 21½ bushels per acre.

It appears that there were 5 bushels per acre more culls on the sprayed rows than on the unsprayed. This is unusual and would

[18] Brainerd & Beaumont had another field of nine acres of potatoes which were planted May 16 to 18 and sprayed five times. The plants in this field were still partially green when frost came. They seemed to die naturally with very little blight, although the soil and other conditions were as favorable to blight as in the field in which the experiment was made. With earlier planting and more spraying it is likely that the gain from spraying in the Gainesville experiment would have reached 100 bushels per acre.

not have occurred in the present case had the plants been given a fifth spraying and the frost delayed so that the plants might have completed their growth.

There was no loss from rot on either sprayed or unsprayed rows.

The gain on the sprayed rows seems to have been due almost wholly to the prolonged growth of the plants and this was the consequence of their having been protected against the ravages of late blight. There was no early blight and no damage done by flea-beetles.

The items of expense for spraying 26 acres four times are as follows:

601 pounds copper sulphate, at 6c..................	$36 06
289 pounds lime, at 1c..............................	2 89
80 hours labor for team, at 15c.......................	12 00
140 hours labor for man, at 15c......................	21 00
57 pounds white arsenic (including cost of sal soda and the expense of preparation), at 10c............	5 70
Wear on sprayer at 5c per acre for each application..	5 20
Total	$82 85

The total cost of spraying per acre was $3.19 and the average cost per acre for each application 80 cents. The market price of potatoes at Gainesville at the time the test rows were dug was 43 cents per bushel of 62 pounds.

THE WEST HENRIETTA EXPERIMENT.

This experiment was made by Robert Dunn at West Henrietta, about nine miles south of Rochester. Twelve acres of potatoes were sprayed eight times on the following dates: July 25, August 2, 9, 16, 23 and 30 and September 6 and 15. Three rows 1,075 feet long, about the middle of the field, were left unsprayed.

The spraying was done with a two-horse, six-row power sprayer made by E. C. Brown & Co., Rochester, N. Y. This sprayer has one nozzle per row and the pumping is done automatically with power obtained from the wheels. (See Plate VIII, fig. 1.) The bordeaux used was made according to the formula: Seven pounds of copper sulphate, six pounds of lime and 55 gallons of water. Paris green was used with the bordeaux only in the

first spraying. It appears that even this application was unnecessary; for the unsprayed rows, which received no poison at all, were entirely uninjured by bugs.

The soil was a sandy loam in a high state of fertility. Having good care and cultivation, and an abundance of fertility the plants made a rank growth completely covering the ground. Under such conditions some would hesitate to spray fearing to injure the vines by driving over them. Note the results in this experiment.

On August 18, when the experiment was first examined by one of the writers, many of the lower leaves on the unsprayed plants were already attacked by late blight, *Phytophthora infestans*. There were also traces of the disease among the sprayed plants.

At the time of our second visit, September 7, there was a marked contrast between the sprayed and unsprayed rows. The latter had lost from one-half to three-fourths of their foliage while the adjacent sprayed rows on both sides were in full foliage with only traces of blight. On the under surface of almost every affected leaf the fine frost-like mildew around the margins of the diseased spots could be distinctly seen. This was an indication that the fungus was in a state of active growth and in a condition to cause rapid destruction of the plants.

Our third visit was made September 22. Now, the unsprayed rows were dead and dry clear across the field while the sprayed rows continued green in all parts of the field except a small area on the south side next the road. The three unsprayed rows appeared as a narrow brown streak extending across a field of green (See Plate VIII, fig. 2). It was a striking example of the benefit of spraying and no one who saw it could any longer doubt that spraying will prevent blight. Fortunately, a public road ran along two sides of the field so that many persons had the opportunity of seeing the experiment.

On the night of September 22, there was a light frost which injured the plants some but did not kill them. When we saw the field for the last time on September 24 the sprayed plants were in fully as good condition as the unsprayed plants were on September 7; that is to say, the sprayed plants outlived the unsprayed by at least 17 days.

The test rows were dug with a potato digger on October 17. The three unsprayed rows and three sprayed rows on either side were dug and weighed separately. The yields are shown in the accompanying table:

TABLE X.—SHOWING YIELDS IN WEST HENRIETTA EXPERIMENT.

ROW.	Treatment.	Yield per Row.[19]		Yield per Acre.			
		Marketable.	Culls.	Marketable.		Culls.	
		Lbs.	Lbs.	Bu.	lbs.	Bu	lbs.
1	Sprayed 8 times	1398	33	323	38	7	38
2	Sprayed 8 times	1372	26	317	37	6	1
3	Sprayed 8 times	1201	52	278	2	12	2
4	Not sprayed	875	82	202	34	18	59
5	Not sprayed	798	51	184	44	11	48
6	Not sprayed	850	25	196	46	5	47
7	Sprayed 8 times	1258	40	291	14	9	16
8	Sprayed 8 times	1347	46	311	50	10	39
9	Sprayed 8 times	1222	46	282	53	10	39

The average yield of the three unsprayed rows (Rows 4, 5 and 6) was 841 pounds or 194 bushels and 41 pounds per acre. The average yield of the six adjacent sprayed rows (Rows 1, 2, 3, 7, 8 and 9), was 1,299¾ pounds, or 300 bushels 52 pounds per acre. The gain due to spraying, computed in this way, is 106 bushels 11 pounds per acre. We believe, however, that this method of computing the gain makes it appear less than it really is. The outside unsprayed rows 4 and 6 received some benefit from spray falling upon them when the adjacent rows 3 and 7 were sprayed. And the first sprayed rows 3 and 7 did not have as good a chance as other sprayed rows in the same field for two reasons: (1) They were not so thoroughly sprayed; (2) they were more exposed to the attack of blight because they stood next to the badly blighted unsprayed rows. This view is supported by the yields. The middle unsprayed row yielded less than either of the other unsprayed rows; and the first sprayed row on either side yielded less than the second sprayed row standing next to it.[20] The same thing has been observed in other experiments. Accordingly, we hold that the proper method of determining the gain is to compare the yield of the middle unsprayed row 5 with the average yield of the two sprayed rows 2 and 8. Computed in this way the yield of the sprayed is 314 bushels 43 pounds per acre

[19] Rows 1,075 feet long and 35 inches apart, 13.89 being required to make an acre.

[20] We are unable to explain why Row 9 yielded less than Row 8.

and of the unsprayed 184 bushels 44 pounds, making the *increase in yield due to spraying 130 bushels per acre.* There was no rot worth mentioning, no early blight and no flea-beetles. The gain was due almost entirely to the prevention of late blight. Mr. Dunn reports that the average yield for the whole field was 297 bushels per acre.

At fifty cents per bushel,[21] which was the market price of potatoes at digging time, the 130 bushels per acre increase in yield was worth $65. Deducting from this $4.89, the average cost of spraying per acre, there remains *$60.11 net profit per acre.* Assuming that the gain due to spraying was at the same rate all over the field the total net profit from spraying the twelve acres was $721.32. Surely spraying was profitable in this case. It was Mr. Dunn's first experience in spraying potatoes.

The items of expense were as follows:

400 pounds copper sulphate at 6c.	$24 00
8 bushels lime at 25c.	2 00
14 pounds paris green at 15c.	2 10
80 hours labor for man at 15c.	12 00
80 hours labor for team at 15c.	12 00
Interest and wear on sprayer	6 60
Total cost spraying 12 acres 8 times	$58 70

The average cost of spraying per acre was $4.89 and the cost per acre for each application 61 cents.

We regard this experiment of Mr. Dunn's as the most satisfactory one of the series. Although the net profit per acre, as given, is remarkably large, we believe it to be very nearly correct if we leave out of consideration the extra expense of handling the increase in yield.[22] However, this can not be done. The

[21] A little less than 1,000 bushels were actually sold at this price and the balance stored.

[22] In these business experiments the extra expense of handling and marketing the increase has been left out of consideration in computing the net profit due to spraying. This is often a considerable item as in Mr. Dunn's experiment; but it seems not unfair to neglect it for the reason that in the expense of spraying the expense of fighting bugs is included. Strictly speaking the expense of fighting bugs should not be included in the expense of spraying for blight because it is something which must be done anyway. The extra expense of handling and marketing the increase must be estimated for

picking up and hauling to market of the increase is all extra labor. Mr. Dunn paid 1½ cents per bushel for picking up the potatoes which makes the extra expense of that item alone $1.95 per acre. He estimates the expense of hauling the potatoes from th field to the cellar at one cent per bushel, sorting one cent per bushel and hauling to market three cents per bushel, making in all an extra expense of 6½ cents per bushel or $8.45 per acre which must be subtracted from the $60.11. This leaves $51.66 per acre or $619.92 for twelve acres. Making ample allowance for errors of all kinds it is safe to say that Mr. Dunn is at least $500 better off for having sprayed his potatoes the past season.

THE SPENCERPORT EXPERIMENT.

This experiment was made by F. E. Gott, Spencerport, N. Y. Two fields of potatoes, one of four acres and one of four and one-half acres, were sprayed six times with a home-made, two horse, three-row sprayer. The sprayer consisted of a two-wheeled cart carrying a fifty-gallon barrel in which was mounted an Empire King spray pump. (See Plate VII, fig. 2). Two men were required to operate it—one to pump and one to drive. There was but one Vermorel nozzle per row. About 38 gallons of bordeaux mixture per acre were applied at each spraying. Both fields were adjacent to a public road and three rows in each field were left unsprayed.

The east field.—In this field the variety was Gold Coin. The unsprayed rows were 554 feet long by 3 feet wide, 26.2 rows being required to make an acre. The dates of spraying were July 25, August 1, 6, 13, 22 and September 10.

When we examined the experiment on August 31 only the merest traces of late blight could be found even on the unsprayed rows. Although the sprayed rows had already received five applications they were only slightly better than the unsprayed. The only disease of any importance was one of unknown cause the symptoms being dwarfed growth, curled leaves with brown-

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the most part; the same is true of the expense of fighting bugs. Hence, we have thought best to assume that these two items offset each other and to leave them both out of account. We believe that the one will about equal the other on the average. Of course this would not be true of the West Henrietta experiment because it so happened that no treatment for bugs was necessary. On the other hand, in the Long Island experiments treatment for bugs constituted a large part of the expense of spraying.

ing of the margins and tips, and foliage lighter green than normal.[23]

On both sprayed and unsprayed rows fully two-thirds of the plants were more or less affected, some of them badly. Spraying seemed to check this disease only slightly.

The test rows were dug with a potato digger on October 15. The middle unsprayed row and the second sprayed row on either side were weighed separately with results as follows:

Second sprayed row on the west, 364 pounds marketable tubers.
Second sprayed row on the east, 397 pounds marketable tubers.
Average of two sprayed rows 380½ pounds marketable tubers.
Middle unsprayed row, 316 pounds marketable tubers.

Yield, sprayed, 166 *bu.* 9 *lbs. marketable tubers per acre.*
Yield, unsprayed, 137 *bu.* 59 *lbs. marketable tubers per acre.*
Gain, 28 *bu.* 10 *lbs. marketable tubers per acre.*

The yield of culls was as follows:

Second sprayed row on the west, 27 pounds.
Second sprayed row on the east, 27 pounds.
Average of two sprayed rows, 27 pounds.
Middle unsprayed row, 19 pounds.
Difference in favor of sprayed rows, 3½ bushels per acre.

The west field.—In this field there were three varieties—Gold Coin, Carman No. 3 and Rural New Yorker No. 2. In the last named variety three rows were left unsprayed. These rows were 920 feet long, three feet apart and 15.78 rows were required to

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[23] We have observed this disease before, most frequently on Long Island. In 1903 there was a little of it in the ten-year experiment at Geneva (see Bul. 241, top of page 260). In the Spencerport experiment no effort was made to determine the cause. In former years we have made a careful examination of the underground parts without being able to locate the trouble. Usually, there are no lesions on the subterranean stem and the seed piece is quite as likely to be sound as otherwise. The roots are scant. It is neither tipburn nor sunscald as these diseases are generally understood. Neither is it the stem blight described in our Bulletin 101, page 83. The symptoms above ground are different and there is no discoloration of the fibro vascular bundles at the stem end of the tubers as in the case of stem blight. In some ways it resembles the rosette disease described by Selby (Ohio Exp. Sta. Buls. 139 and 145), but Rhizoctonia is not associated with it. Undoubtedly, the cause of the trouble is to be sought below ground. In the Spencerport experiment the "seed" appears to have been weak. Many of the "seed" pieces failed to grow, the result being a thin stand of plants.

make an acre. The soil was a well drained sandy loam somewhat lighter than in the east field. Six applications of bordeaux mixture were made on the following dates: August 1, 6, 13, 23, September 3 and 10. The spraying was done with the same outfit used in the east field and in the same manner.

On August 31 there were traces of late blight, *Phytophthora infestans,* all along the unsprayed rows, but no material injury was done as yet. The sprayed rows appeared only slightly better than the unsprayed, being wholly free from late blight and somewhat darker green in color. Among the varieties Rural New Yorker No. 2 and Gold Coin there were a good many plants affected with the unknown leaf curl found in the east field; but the Carman No. 3 was entirely free from it.

The test rows were dug with a potato digger on October 15, the yields being as follows:

Second sprayed row on the east,[24] 410 pounds of marketable tubers or 107 bushels 50 pounds per acre.

Middle unsprayed row, 356 pounds of marketable tubers or 93 bushels 38 pounds per acre. Thus the gain due to spraying was 14 bushels 12 pounds of marketable tubers per acre.

On the unsprayed row there were 52 pounds of culls and on the sprayed row 36 pounds, making a difference of 4 bushels and 12 pounds of culls per acre in favor of the unsprayed.

Summary.—Averaging the results in the two fields we have the following:

Yield, sprayed, 136 *bu.* 59 *lbs. of marketable tubers per acre.*
Yield, unsprayed, 115 *bu.* 48 *lbs. of marketable tubers per acre.*
Gain, 21 *bu.* 11 *lbs. of marketable tubers per acre.*

There was practically no loss from rot in either field. There having been so little blight, the gain due to spraying was as large as could be expected. The only important disease in either field was the previously mentioned leaf curl which is only slightly preventable by spraying. No doubt farmers sometimes confuse this disease with early and late blight, but it is readily distinguished from both these blights by the fact that it attacks only the margins and tips of the leaves.

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[24]The yield of the second row on the west was not taken because it was found to be of a different variety.

The items of expense for spraying both fields (8½ acres) are as follows:

192 pounds blue vitrol at 6¼c.	$12 00
Lime	1 30
75½ hours labor for man, at 15c.	11 32
37¾ hours labor for team, at 15c.	5 67
Interest and wear on sprayer.	2 55
Total	$32 84
Total cost of spraying per acre.	$3 86
Cost per acre for each application.	64

It will be observed that the expense account contains no mention of poison for bugs. None was needed. There were no bugs even on the unsprayed rows. Mr. Gott states that for several years past he has had very little trouble from bugs. Usually there are so few that no treatment is necessary. Why this should be so is not clear.

About digging time Mr. Gott sold a considerable part of his crop for fifty cents per bushel. At this price the increase per acre, 21 1-6 bushels, would be worth $10.58. Subtracting $3.86, the expense of spraying, there is left a *net profit of* $6.72 *per acre.*

THE CLIFTON SPRINGS EXPERIMENT.

This experiment was made by P. H. Pettit, near Clifton Springs, in Ontario County. It included one field of eight acres and another of four, making twelve acres in all. Both fields were sprayed five times. Three rows in the eight-acre field were left unsprayed. They were 898 feet long and three feet apart, 16.16 rows being required to make an acre.

The variety was Carman No. 3. The soil in both fields was a very sandy loam. The eight-acre field was late planted (June 13) and the sprayed plants were still growing, when frost came. The four-acre field was planted June 4.

The spraying was done with a four-row power sprayer made by E. C. Brown & Co., Rochester, N. Y. (See Plate IX, fig. 2.) It carries one nozzle for each row and is intended to be hauled by one horse, but the soil being sandy and the field somewhat

hilly, Mr. Pettit thought best to fit the sprayer for use with two horses. The dates of spraying in the field in which the test rows were located were as follows:—July 20, August 1, 13 and 25 and September 7. The bordeaux used was made by the usual formula; namely, six pounds of copper sulphate, four pounds of lime and fifty gallons of water. The eight-acre field was about 100 rods from the water supply, but the smaller field was nearer. There were so few bugs that it was unnecessary to use poison.

Mr. Pettit states that the unsprayed rows began to show blight about August 13. When one of the writers examined the experiment on August 24 the unsprayed rows showed no marked contrast to the sprayed, but upon going among the plants it was readily seen that blight was thoroughly established throughout the greater part of the length of the rows. At the south end one-third of the foliage was ruined by blight. The sprayed plants, also, showed a little blight, but they were not nearly as bad as the unsprayed.

On September 21, the day before frost, the condition of the plants was as follows:—Throughout one-fifth of the distance across the field from the south end the unsprayed rows were completedly dead and dry. In the same region the plants on the sprayed rows adjacent still retained about one-third of their foliage. Over the next two-fifths of their length the unsprayed rows were dead, but the stems of the plants were still succulent. Sprayed plants adjacent were about half dead. Over the remaining two-fifths of their length the unsprayed rows were half dead while the sprayed rows adjacent were uninjured by blight. (Plate IX, fig. 1, shows the test rows at the south end as they appeared on September 6.)

All of the damage was caused by late blight, *Phytophthora infestans*. The greater virulence in the southern portion of the field seems to have been chiefly due to the influence of a piece of timber on the south. Plants next the timber were shaded for two hours or more every morning. Consequently, both dew and rain remained longer on these plants, thereby furnishing excellent conditions for the growth and propagation of the blight fungus. Plants next the timber blighted first and then the disease spread toward the north.

The test rows were dug and weighed on October 25. The yields were as follows:

Second sprayed row on the west, 625 pounds marketable tubers.
Second sprayed row on the east, 580 pounds marketable tubers.
Average of two sprayed rows, 602½ pounds marketable tubers.
Middle unsprayed row, 293 pounds marketable tubers.

Yield, sprayed, 162 bu. 16 lbs. marketable tubers per acre.
Yield, unsprayed, 78 bu. 55 lbs. marketable tubers per acre.
Gain, 83 bu. 21 lbs. marketable tubers per acre.

The yield of culls was at the rate of 22 bushels 29 pounds per acre on the sprayed rows and 29 bushels 5 pounds per acre on the unsprayed, the difference being 6½ bushels, per acre in favor of the unsprayed.

There was no rot. The total yield from the twelve acres was 2330 bushels, or an average of 194 bushels per acre.

The items of expense of spraying the twelve acres are as follows:

417 pounds copper sulphate at 6½	$27 10
200 pounds lime at 1c	2 00
60 hours labor for team at 15c	9 00
70 hours labor for man at 15c	10 50
Interest on cost of sprayer ($65 at 6%)	3 90
Wear on sprayer (5c per acre each spraying)	3 00
Total	$55 50

Total cost of spraying per acre	$4 62½
Cost per acre for each spraying	92½

At 40 cents per bushel, the market price of potatoes at digging time, 83 1-3 bushels of potatoes would be worth $33.33. Subtracting $4.63, the cost of spraying per acre, there remains *a net profit of $28.70 per acre.*

Although there were five other farmers' business experiments in which the gain per acre was more than 83 1-3 bu., the Clifton Springs experiment ranks first in the percentage of gain, which was 105.6 per ct. Spraying more than doubled the yield. If

frost had not come until after the plants had finished their growth the gain due to spraying would have been still larger.

THE DENMARK EXPERIMENT.

This experiment was made by H. E. Cook at Denmark in Lewis County. Two and three-fourths acres of potatoes were sprayed four times—July 14, 28, August 15 and 27.

There were two varieties in the field—Carman No. 3 and Rural New Yorker No. 2. In the latter variety three rows were left unsprayed. These rows were 586 feet long and 3 1-3 feet apart, 22¼ rows being required to make an acre. The soil was a sandy loam with some gravel in it.

The spraying was done with an "Aroostook" two-horse power sprayer covering four[25] rows at each passage with one Vermorel nozzle over each row. In the first three sprayings paris green was used with the bordeaux at the rate of one pound to fifty gallons. At the time of the first spraying the unsprayed rows were treated with paris green in water. At the time of the second spraying the unsprayed rows were accidentally sprayed with bordeaux and paris green the same as the sprayed rows. On August 15 when the third spraying was made bugs were plentiful and poison should have been applied to the unsprayed rows, but it was neglected, with the result that bugs injured the unsprayed rows considerably.

When the experiment was examined on September 13 there was a little blight on both sprayed and unsprayed rows, but no material damage had been done. The plants were killed by frost on September 21.

The test rows were dug by hand on October 7. The yields were as follows:

Second sprayed row on the north, 561 pounds marketable tubers.

Second sprayed row on the south, 580 pounds marketable tubers.

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[25] The sprayer was intended to spray six rows at a time, but owing to the unusual width of the rows (3⅓ feet) it was necessary to rearrange the nozzles, and in doing this the change to four rows was made for the sake of convenience. In the third spraying extra nozzles were added so that every other row received spray from two nozzles. Mr. Cook states that on the double-sprayed rows the spraying was much more thoroughly done. He is of the opinion that two nozzles per row are needed when the vines become large.

Average of the two sprayed rows, 570½ marketable tubers.
Middle unsprayed row, 512 pounds marketable tubers.

Yield, sprayed, 211 *bu.* 33 *lbs. marketable tubers per acre.*
Yield, unsprayed, 189 *bu.* 52 *lbs. marketable tubers per acre.*
Gain, 21 *bu.* 41 *lbs. marketable tubers per acre.*

The yields of culls, including both small and rotten tubers, was at the rate of 22 bushels 4 pounds per acre on the sprayed rows and 21 bushels 8 pounds on the unsprayed. Fully one-half the culls consisted of rotten tubers in the early stages of decay and apparently there was just as much rot on the sprayed as on the unsprayed rows. All of the rot seemed to be of the kind which follows late blight, *Phytophthora infestans.* This is proof that there was some late blight in the field, on the sprayed as well as on the unsprayed rows. A fifth spraying, made about September 10, would probably have prevented most of the rot.

The items of expense of spraying two and three-fourths acres were as follows:

100 pounds copper sulphate, at 7c.	$7 00
100 pounds lime, at ½c.	50
8 pounds paris green, at 15c.	1 20
3⅓ days labor for man, at $1.50	5 00
1⅔ days labor for team, at $1.50	2 50
Wear on sprayer	3 00
Total	$19 20

Total cost of spraying per acre	$6 98
Cost per acre for each spraying	1 74½

In this experiment the cost per acre for each application is high, being more than twice as great as in other experiments made with the same kind of sprayer.[26] This is largely owing to the long distance (one mile) which it was necessary to haul water for making the bordeaux.

Soon after digging, the potatoes were sold for fifty cents per bushel. At this price 21⅔ bushels would be worth $10.83. Subtracting $6.98, the cost of spraying per acre, there remains *a net profit of $3.85 per acre.*

[26]See pp. 107, 126, 158, 161 and 162; also Bul. 241, pp. 273, 275 and 278.

The results in this experiment are not of much value. Part of the increase in yield on the sprayed rows was due to their having been protected from bugs while the unsprayed rows were neglected and suffered considerably from bugs. Matters were further complicated by the accidental spraying of the three unsprayed rows. Mr. Cook thinks that this spraying afforded the unsprayed rows considerable protection against late blight and his view is supported by the fact that his potato field, including the unsprayed rows, remained green after all others in the neighborhood were dead from blight.

THE MADRID EXPERIMENT.

This experiment was made by W. E. Griffith at Madrid in St. Lawrence County. Two and two-thirds acres were sprayed four times. The variety was Carman No. 3. The soil was a fertile clay loam. The potatoes were planted early but came out poorly, making a thin stand of plants. Three rows 614 feet long and 3 feet apart were left unsprayed. To make an acre required 23.64 rows.

The spraying was done with a home-made outfit consisting of a one-horse, two-wheeled cart carrying a fifty-gallon barrel with a hand spray pump attached and arranged to spray three rows at a time with two Vermorel nozzles per row. (See Plate X, fig. 1.) A one-armed man did both the pumping and driving. It was necessary to haul the bordeaux about 40 rods.

The dates of spraying were June 30, July 11, 16 and 27. At each spraying paris green was used with the bordeaux at the rate of one pound to fifty gallons. In addition, the plants were treated twice with paris green in water at the same rate, making in all six applications of poison to the sprayed rows. The unsprayed rows were given seven applications of paris green in water, one pound to fifty gallons. It would seem that this very thorough treatment should have kept bugs entirely under control, but Mr. Griffith reports that it did not and that the unsprayed rows were slightly more injured by bugs than those sprayed.

No record was kept of the progress of blight. All we know is that the unsprayed rows were considerably affected by late blight on August 6, and that both sprayed and unsprayed plants died

prematurely. On September 12, the plants were all dead and the field overgrown with weeds. Mr. Griffith thinks that a fifth spraying would have been very beneficial.

The test rows were dug with a plow on October 6. The yields were as follows:

Second sprayed row on the north, 307 pounds marketable tubers.
Second sprayed row on the south, 235 pounds marketable tubers.
Average of the two sprayed rows, 271 pounds marketable tubers.
Middle unsprayed row, 180½ pounds marketable tubers.

Yield, sprayed, 166 *bu.* 46 *lbs. marketable tubers per acre.*
Yield, unsprayed, 71 *bu.* 7 *lbs. marketable tubers per acre.*
Gain, 35 *bu.* 39 *lbs. marketable tubers per acre.*

The yield of culls was at the rate of 6 bushels and 54 pounds per acre on the sprayed and 8 bushels and 28 pounds on the unsprayed. There were a few rotten tubers among both sprayed and unsprayed and these were included with the culls.

The items of expense of spraying $2\frac{2}{3}$ acres were as follows:

114 pounds copper sulphate at 6c	$6 84
76 pounds lime at 1c	76
27 pounds paris green at 20c	5 40
16 hours labor for man at 15c	2 40
16 hours labor for horse at 10c	1 60
Wear on sprayer	1 00
Total	$18 00

Total cost of spraying per acre	$6 75
Cost per acre for each spraying	1 69

The cost of spraying was greatly increased by the enormous quantity of paris green used. This item amounted to $2.02 per acre.

At digging time the market price of potatoes was 30 cents per bushel, but early in November it rose to 50 cents. At 30 cents per bushel 35 2-3 bushels would be worth $10.70. Subtracting $6.75, the cost of spraying per acre, there remains *a net profit of $2.95 per acre.*

THE MALONE EXPERIMENT.

This experiment was conducted by Nelson W. Porter, Malone, N. Y. Eight acres of potatoes were sprayed seven times. Three rows 1452 feet long were left unsprayed for a check.

The soil was sandy loam and the previous crop timothy hay. Five tons of high grade commercial fertilizer were used on the eight acres. The potatoes were of the variety Carman No. 3. They were planted May 27 five inches deep, 13½ inches apart in the row and the rows three feet apart. They were given six cultivations without any hilling and no hand hoeing except over a small area infested with quack grass.

The spraying was done with a one-horse, four row "Iron Age" sprayer manufactured by the Bateman Manufacturing Co., Grenloch, N. J., (See Plate X, fig. 2.) The dates of spraying were July 8, 18, 27, August 2, 15, 25 and 31. Paris green was used with the bordeaux in the first two sprayings at the rate of one and one-half pounds per acre. The unsprayed rows were treated with paris green on the same dates.

Until well toward the close of the season there was no marked difference between the sprayed and unsprayed plants. On September 9 the unsprayed plants were smaller and appeared less vigorous than the sprayed. They also showed some injury from early blight, but late blight was present only in small amount. Flea-beetles gave no trouble at any time. A few days before the plants were killed by frost on September 22 there was an outbreak of late blight which damaged the unsprayed rows considerably but did not affect those sprayed.

Considering that there had been so little blight until late in the season and no conspicuous contrast in appearance of the foliage on sprayed and unsprayed rows it was not expected that there would be a great difference in yield. Consequently it was a surprise to find that the sprayed rows outyielded the unsprayed at the rate of 115 bushels per acre. (See Plate XI.) The test rows were dug by hand on October 5, the yields being as follows:

Second sprayed row on the north, 2017 pounds marketable tubers.

Second sprayed row on the south, 2022 pounds, marketable tubers.

Average of the two sprayed rows, 2019½ pounds marketable tubers.

Middle unsprayed row, 1331 pounds, marketable tubers.

Yield per acre, sprayed, 336 *bu.* 35 *lbs. marketable tubers.*
Yield per acre, unsprayed, 221 *bu.* 50 *lbs. marketable tubers.*
Gain per acre, 114 *bu.* 45 *lbs. marketable tubers.*

The yield of tubers below marketable size was at the rate of 24¾ bushels per acre on the sprayed and 37⅔ bushels on the unsprayed.

On the unsprayed row there were 116 pounds of rotten tubers, which is at the rate of 19 1-3 bushels per acre, while on the sprayed rows there was practically no rot—7 pounds on one row and 4 pounds on the other. Furthermore, the sprayed potatoes kept well in storage. Thus it is plain that spraying checked the rot, but it is strange that there was not more rot on the unsprayed row. In the majority of potato fields in the vicinity of Malone there was much rot owing to the abundant rains in the latter part of September. In a field lying just across the road at the east end of the experiment field, on the same kind of soil and with equally good growth of vines, the yield was about 30 bushels of marketable tubers per acre, the remainder being rotten; while in another field across the road at the west end of the experiment field about one-half of the tubers were rotten. For some reason the unsprayed rows in Mr. Porter's experiment did not blight as badly as did neighboring fields which were not sprayed and of course there was less rot. Another thing which protected Mr. Porter's potatoes from rot to some extent is the fact that they were deep-planted. Deep-planted potatoes usually rot less than shallow-planted ones.

The total yield of marketable potatoes on the eight acres was 2940 bushels which is at the rate of 367½ bushels per acre. Although the yield was so large, scarcely any of the tubers were overgrown. The entire crop was sold at from 40 to 45 cents per bushel.

The items of expense for spraying eight acres seven times in the Malone experiment were as follows:

310 pounds copper sulphate at 5¾c	$17 82
24 pounds paris green at 15c	3 60
250 pounds lime at one-half cent	1 25
70 hours labor for man at 15c	10 50
70 hours labor for horse at 5c	3 50
Allowance for wear of sprayer	10 00
Total	$46 69
Total cost per acre for seven sprayings	$5 83
Cost per acre for each spraying	83⅓

At 40 cents per bushel 114¾ bushels of potatoes would be worth $45.90. Subtracting $5.83, the cost of spraying, there remains *a net profit of $40.07 per acre.*

THE PERU EXPERIMENT.

This experiment was conducted by Datus Clark at Peru in Clinton County. Sixteen acres were sprayed four times. There were two varieties; namely, Green Mountain and White Giant. Six rows about 80 rods long and running cross-wise of both varieties were left unsprayed. The soil was sandy loam. The nearest point of the field was sixty rods from the water supply. The spraying was done with a six-row, two-horse " Aroostook " power sprayer made by the Field Force Pump Co., Elmira, N. Y. The sprayer was fitted with one Vermorel nozzle for each row. The dates of spraying were July 18, 29, August 9 and 22. Paris green was used with the bordeaux twice. Perhaps this was unnecessary. Although no poison whatever was applied to the unsprayed rows they were not injured by bugs.

At no time during the season was there any blight of importance even on the unsprayed rows. However, there must have been a little late blight, *Phytophthora infestans,* because a few rotten tubers were found. On September 9, when the experiment was examined by one of the writers, it was impossible to distinguish the unsprayed rows. No trace of late blight could be found at this time. The plants were large and healthy except for a slight spotting of the foliage the cause of which was not definitely determined. Other potato fields in the vicinity were looking well with almost no indication of blight.

The test rows were dug by hand on October 3. Since the rows were so long and Mr. Clark very busy, it was decided to dig and weigh only 300 feet of each variety. In each variety the yield was taken of the middle two unsprayed rows and of the second sprayed row on either side with the following results:

Green Mountain: Two sprayed rows, 490 lbs. marketable tubers.

Green Mountain: Two unsprayed rows, 580½ lbs. marketable tubers.

Yield per acre, sprayed, 197 bu. 38 lbs. marketable tubers.

Yield per acre, unsprayed, 205 bu. 6 lbs. marketable tubers.

White Giant: Two sprayed rows 270½ lbs. marketable tubers.

White Giant: Two unsprayed rows, 268 lbs. marketable tubers.

Yield per acre, sprayed 109 bu. 6 lbs. marketable tubers.

Yield per acre, unsprayed, 108 bu. 6 lbs. marketable tubers.

Average yield per acre, sprayed, 153 *bu.* 22 *lbs. marketable tubers.*

Average yield per acre, unsprayed, 156 *bu.* 36 *lbs. marketable tubers.*

Loss per acre, 3 *bu.* 14 *lbs. marketable tubers.*

The average yield of culls (small tubers only) was 3¾ bu. per acre on the sprayed and 7½ bu. on the unsprayed.

The rotten tubers were not weighed. There were none at all in the variety White Giant and only a few in the Green Mountain.

Owing to late planting, the plants were in full foliage on September 21 when frost came. Had there been time for the plants to mature the yields would have been larger.

The items of expense of spraying the sixteen acres were as follows:

121 pounds copper sulphate at 10 cents	$12 10
78 pounds lime at 1 cent	78
12 pounds paris green at 20 cents	2 40
24 hours' labor for team at 25 cents	6 00
24 hours' labor for man at 15 cents	3 00
Wear on sprayer	4 00
Total	$28 88
Total cost of spraying per acre	$1 80
Cost per acre for each spraying	45

At digging time the market price of potatoes was 35 cents per bushel. At this price 3¼ bushels would be worth $1.14. Adding to this $1.80, the cost of spraying, we have in this experiment a loss of $2.94 per acre.

Although the sprayed rows yielded less than the unsprayed it is very improbable that the plants were injured by the spraying. The small difference in yield, 3¼ bushels per acre, may easily have been due to slight differences in soil. Differences much greater than this often occur between adjacent rows treated as nearly as possible in the same way. Examples of wide difference in yield between rows close together and treated exactly alike may be seen in Tables V and VII on pages 100 and 103 respectively.

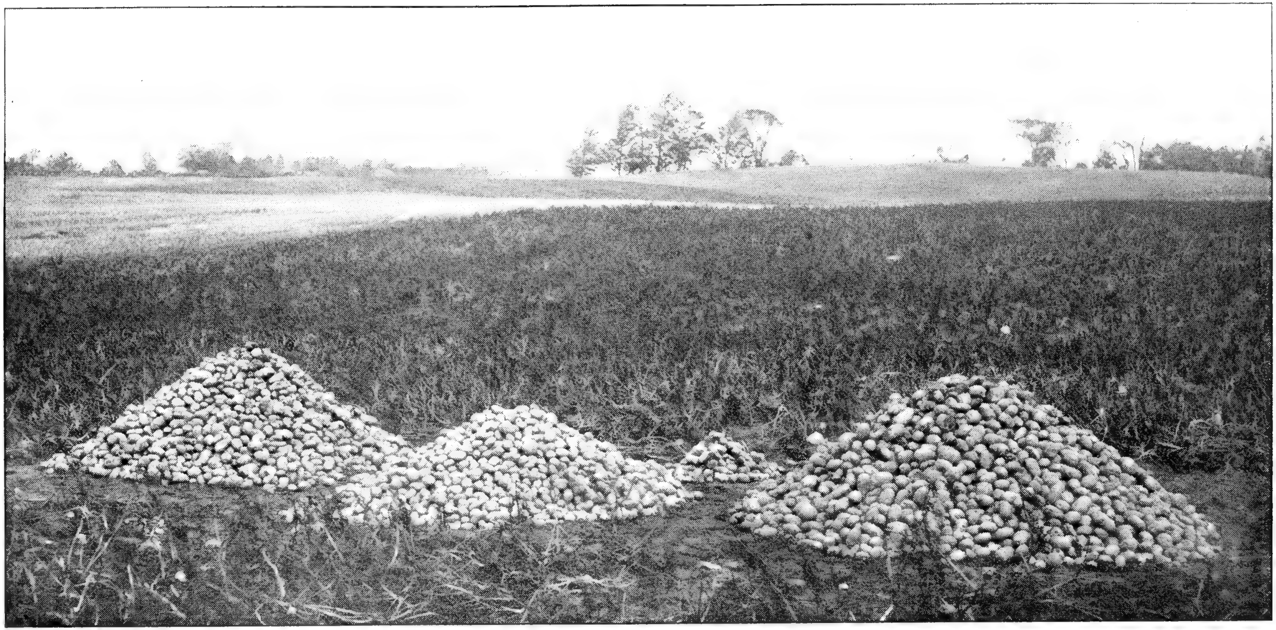
This was Mr. Clark's first experience with spraying potatoes. In fact very little spraying has ever been done at Peru although the potato crop is an important one there. In spite of the unsuccessful outcome of Mr. Clark's experiment we believe that, one year with another, it will pay to spray potatoes in that section. Another experiment will be made in 1905. It can scarcely be possible that potatoes are exempt from blight at Peru. At Burlington, Vt., only a few miles distant, late blight is destructive nearly every season. The Vermont Experiment Station, located at Burlington, has made potato spraying experiments every season since 1891, the average gain for fourteen years being 125½ bushels per acre. Strange to say, the largest gain was obtained in 1904 when plants sprayed twice outyielded unsprayed plants at the rate of 261 bushels of marketable tubers per acre. The gain was due chiefly to a reduction in the amount of rot among the tubers.

THE SLITERS EXPERIMENT.

This experiment was made by John S. Middleton about eight miles southeast of Albany. Three acres of potatoes were sprayed with a five-gallon, compressed-air sprayer bought of the Rochester Spray Pump Company, Rochester, N. Y. (Plate XVI, fig. 1.) The potatoes were of the variety Late Delaware planted in hills two feet six inches apart each way. The soil was a shaly loam. Three rows 600 feet long were left unsprayed. The entire field excepting the three unsprayed rows was sprayed twice and one-half the field was sprayed a third time. The unsprayed rows were in the portion sprayed three times. The dates of spraying were: First, July 11 and 12; second, July 27 and 28; third, August 8 and 9.

FIG. 1.—THE CLIFTON SPRINGS EXPERIMENT.
Photographed Sept. 6   Gain due to spraying, $83\frac{1}{3}$ bushels per acre.

FIG. 2.—SPRAYING IN THE CLIFTON SPRINGS EXPERIMENT.
PLATE IX.



Sprayed, 33.7 bu. Unsprayed, 22.2 bu. Sprayed, 33.6 bu.

PLATE XI.—THE MALONE EXPERIMENT: MIDDLE PILE, PRODUCT OF MIDDLE UNSPRAYED ROW; END PILES, PRODUCT OF SECOND SPRAYED ROW ON EITHER SIDE; SMALL PILE IN REAR, ROTTEN TUBERS (116 LBS.) FROM THE UNSPRAYED ROW.

FIG. 1.—SPRAYING IN THE FARMINGDALE EXPERIMENT.

FIG. 2.—SPRAYING IN THE SOUTHAMPTON EXPERIMENT.

PLATE XII.

Fig. 1.—Spraying in the Mattituck Experiment.

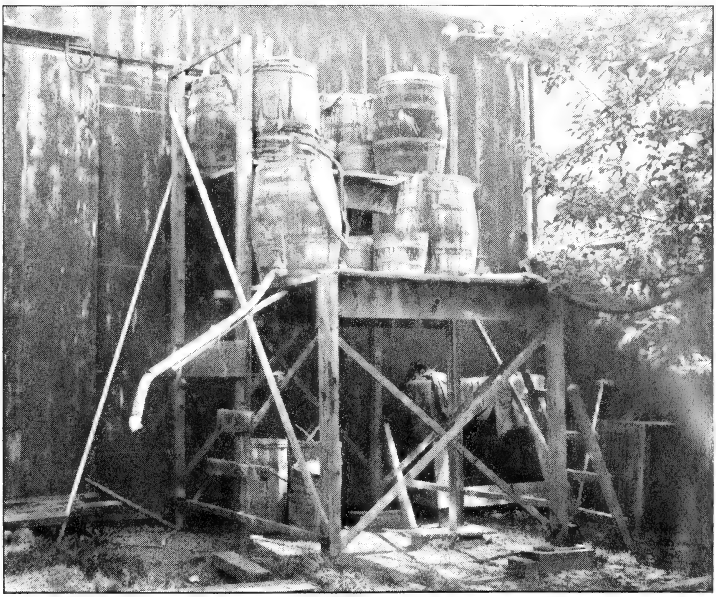


Fig. 2.—Excellent Facilities for Making Bordeaux.
Property of W. H. Satterly and E. D. Ruland, Mattituck, N. Y. See footnote on p. ~~146~~.

Plate XIII.

FIG. 1.—VOLUNTEER EXPERIMENT NO. 16.

By D. S. Norris, West Rush, N. Y. Gain due to spraying, 196 bushels per acre.

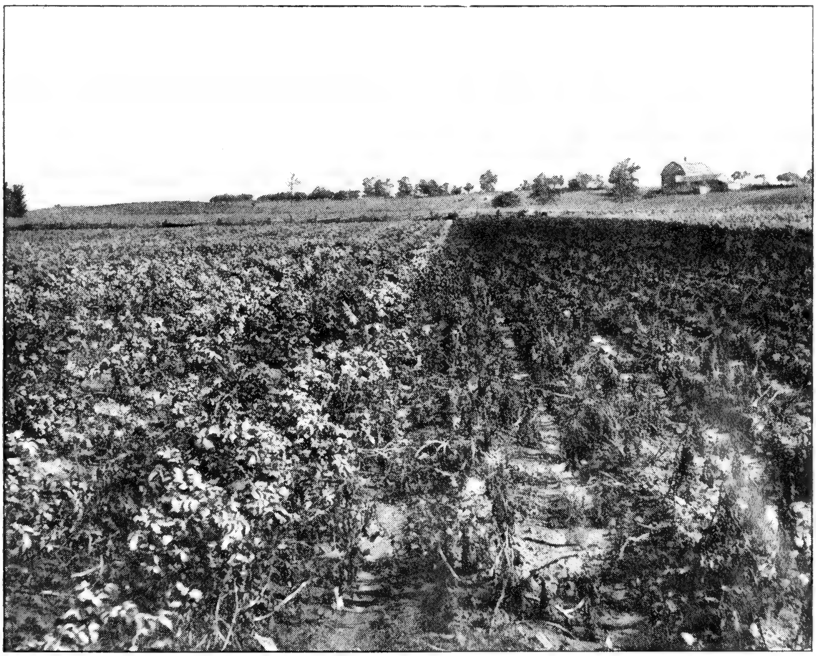


FIG. 2.—VOLUNTEER EXPERIMENT NO. 17.

By T. E. Martin, West Rush, N. Y. Gain due to spraying, 62 bushels per acre. Photographed Sept. 22.

PLATE XIV.

PLATE XV.—VOLUNTEER EXPERIMENT NO. 27.

By H. W. Hadlow, Geneva, N. Y. Photographed Aug. 23. Gain due to spraying, 156 bushels per acre.

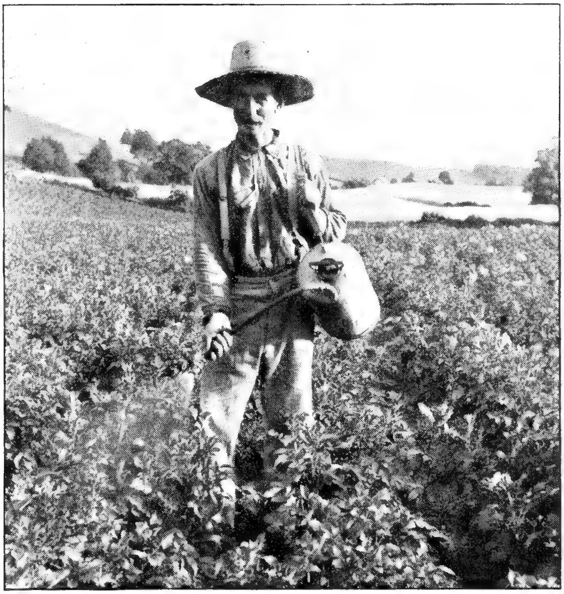


Fig. 1.—Spraying in the Sliters Experiment.

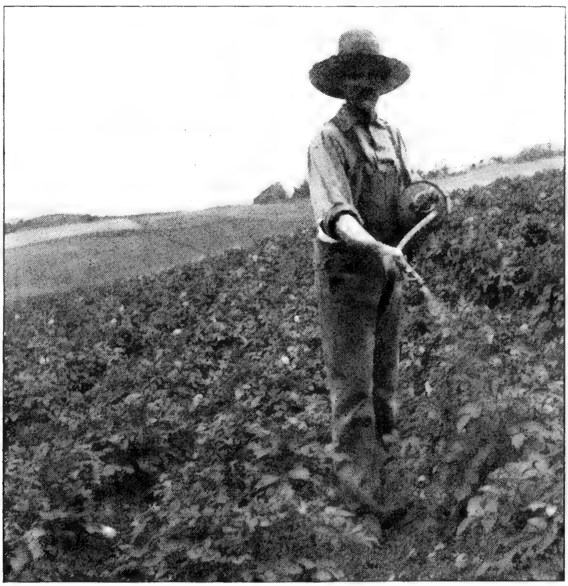
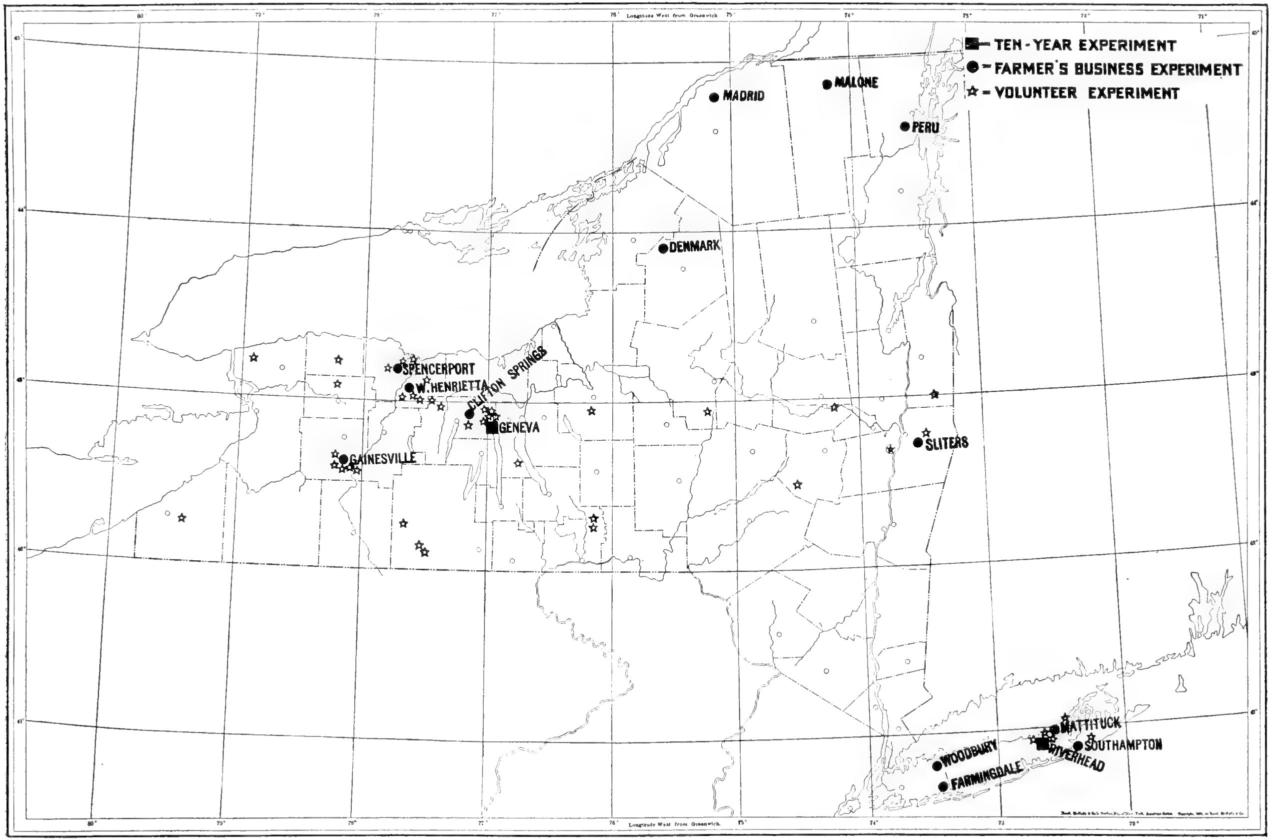


Fig. 2.—Using a Compressed-Air Sprayer in Volunteer Experiment No. 36.

A sprayer of this kind is useful in gardens but not adapted to large fields.

Plate XVI.



Map I.—Location of Potato-Spraying Experiments in 1904.

On August 12 there seemed to be no difference whatsoever between the sprayed and unsprayed rows. The plants were healthy but not large. There was neither early nor late blight and no damage from flea-beetles. During the preceding three weeks there had been but little rain and the weather conditions were unfavorable to blight. Up to the time the plants were killed by frost there was very little contrast in appearance between the sprayed and unsprayed rows. Nevertheless, when the test rows were dug on September 30, the sprayed rows were found to outyield the unsprayed sufficiently to cover all expense of spraying and leave a small net profit. The yields were as follows:

Second sprayed row on the west, 314 lbs. marketable tubers.
Second sprayed row on the east, 311 lbs. marketable tubers.
Average of the two sprayed rows, 312½ lbs. marketable tubers.
Middle unsprayed row, 262 lbs. marketable tubers.

Yield per acre, sprayed, 151 *bu.* 15 *lbs. of marketable tubers.*
Yield per acre, unsprayed, 126 *bu.* 48 *lbs. of marketable tubers.*
Gain per acre, 24 *bu.* 27 *lbs. of marketable tubers.*

The yield of culls was 30 bushels 29 pounds per acre for the sprayed and 32 bushels 55 pounds for the unsprayed.

There was no rot. The total yield of the three acres was 200 barrels of 600 bushels, which is at the rate of 200 bushels per acre.

The items of expense[27] of spraying three acres three times are as follows:

446 gallons bordeaux mixture..........	$4 14
63 hours' labor at 15 cents..........	9 45
4 pounds arsenate of lead[28] at 25 cents	1 00
1 pound paris green	16
Total	$14 75
Total cost of spraying per acre..........	$4 92
Cost per acre for each spraying..........	1 64

[27] The actual expense was less than here given because in the third spraying only one-half the field was sprayed. These figures show what the expense would have been for three full sprayings.

[28] In our opinion it is not advisable to use arsenate of lead for poison on potatoes. It is too expensive. Paris green and arsenite of soda are both considerably cheaper, equally effective and do not injure the foliage if applied with bordeaux mixture as they should be applied.

At digging time the market price of potatoes in Albany was $1.25 per barrel or 41 cents per bushel. At this rate 24½ bushels of potatoes would be worth $10.04. Subtracting $4.92, the cost of spraying, there remains *a net profit of $5.12 per acre.*

In this experiment, as in some others, the yields would have been larger and the gain due to spraying greater if the plants had had a chance to mature before frost.

THE WOODBURY EXPERIMENT.

This experiment was made by R. C. Colyer at Woodbury on Long Island. Fourteen acres were sprayed seven times with a "Watson" sprayer bought of the Field Force Pump Company, Elmira, N. Y. This is a one-horse power sprayer which covers four rows at each passage. (See Plate XII, fig. 2.) It is fitted with one Vermorel nozzle per row and was so used in the first three sprayings; but when the vines became large, Mr. Colyer, finding that the plants were not being thoroughly covered by the spray, put on two nozzles per row. This proved satisfactory.

The soil was sandy loam. There were two varieties, namely, Gold Coin and Green Mountain. In the latter variety three rows were left unsprayed. They were 790 feet long by three feet wide, 18.38 rows being required to make an acre.

The dates of spraying were June 22, 29; July 6, 15, 24; August 3 and 12. Paris green for bugs was used with the bordeaux in the first spraying at the rate of 1½ pounds to fifty gallons. The unsprayed rows were treated once with paris green applied dry with a Leggett powder gun.

The experiment was examined by one of the writers on July 23. Already there was a marked contrast in appearance between the sprayed and unsprayed rows. The unsprayed rows showed considerable injury from early blight, *Alternaria solani,* and flea-beetles. Late blight, *Phytophthora infestans,* was also a factor, but less important than the other two. Even on the sprayed portions of the field flea-bettles were very plentiful and doing some damage, but not nearly as much as on the unsprayed rows.

On August 11 the experiment was inspected a second time. The unsprayed rows were now dead and dry throughout their entire length. The sprayed rows adjacent still retained about

three-fourths of their foliage making the contrast between the sprayed and unsprayed very striking. The unsprayed rows were so completely dried up that it was impossible to determine what had killed them; but the sprayed rows showed evidence of a severe attack of flea-beetles. On the sprayed rows adjacent to the unsprayed there was but little late blight although in some other parts of the field it was abundant.

The test rows were dug on September 19. As usual, weights were taken on the middle unsprayed row and the second sprayed row on either side. The yields were as follows:

Second sprayed row on the west, 997 lbs. marketable tubers.
Second sprayed row on the east, 949 lbs. marketable tubers.
Average of the two sprayed rows, 973 lbs. marketable tubers.
Middle unsprayed row, 624 lbs. marketable tubers.

Yield per acre, sprayed. 298 *bu.* 3 *lbs. marketable tubers.*
Yield per acre, unsprayed, 191 *bu.* 9 *lbs. marketable tubers.*
Gain per acre, 106 *bu.* 54 *lbs. marketable tubers.*

The yield of culls was at the rate of 14¾ bushels per acre for the sprayed area and 22 1-5 bushels for the unsprayed.

The loss from rot was small on both the sprayed and the unsprayed rows. The increased yield on the sprayed rows was mostly due to longer growth of the vines. Flea-beetles, early blight and late blight were all factors in this experiment. Flea-beetles were especially destructive. Mr. Colyer states that he has rarely known them to be so numerous and that they seemed to be worse in his field than in most other fields in the vicinity. These troublesome little insects are scarcely affected by poisons applied in the ordinary way, but by spraying very thoroughly with bordeaux mixture and paris green their ravages may be greatly reduced. In this experiment they caused considerable damage to the sprayed rows in spite of the spraying, while the unsprayed rows were ruined by them.

The items of expense of spraying 14 acres seven times in the Woodbury experiment are as follows:

630 pounds copper sulphate, at 5¾c.	$36 23
2 barrels lime, at $1.40	2 80
22 pounds paris green, at 17c.	3 74
140 hours labor for man, at 15c.	21 00

70 hours labor for horse, at 10c.	$7 00
Wear on sprayer, at 25c. per acre	3 50
Total	$74 47
Total cost of spraying per acre	$5 32
Cost per acre for each spraying	76

At the time of digging the test rows the market price of potatoes was $1.75 per barrel or 60 cents per bushel at Wallabout Market in Brooklyn, where Mr. Colyer markets most of his potatoes. Later the price rose, being $2 per barrel on November 14. At 60 cents per bushel 106 5-6 bushels would be worth $64.10. Subtracting $5.32, the expense of spraying, there remains *a net profit of $58.90 per acre.*

THE FARMINGDALE EXPERIMENT.

This experiment was made by R. E. Colyer at Farmingdale on Long Island. Fifteen acres of potatoes were sprayed four times. Three rows 680 feet long, 2½ feet apart, were left unsprayed for a check. The soil was sandy loam. The potatoes were of the variety Carman No. 3.

The dates of spraying were June 27, July 11, 25 and August 4. The sprayer used was a two-horse, home-made rig covering six rows at a time with two nozzles per row. The spray pump was bought of the Spramotor Co., Buffalo, N. Y. In the first spraying the pumping was done by hand, but afterward with power obtained from the wheels. (Plate XII, fig. 1.) Bordeaux mixture was applied at the rate of about 60 gallons per acre in each spraying. Water for preparing the bordeaux was obtained from a pond about twenty rods distant.

On July 23 there were traces of late blight on sprayed and unsprayed rows. Flea-beetles and plant lice were abundant in all parts of the field. There was no early blight.

On August 11 the plants on the unsprayed rows were dead, but the stems were not yet dry. They had been killed by late blight and flea-beetles, chiefly the former. At the same time about three-fourths of the leaves on the adjacent sprayed plants were still green, the other one-fourth being affected with late blight. A fifth spraying at this time would have been very bene-

ficial, but owing to the pressure of other work it was impossible to make it. Moreover, the field was overgrown with large weeds which covered the potato plants to such an extent that it would not have been possible to reach more than about one-half of the plants with the spray.

The test rows were dug with a double mold-board plow on October 18. The yields were as follows:

Second sprayed row on the west, 273 lbs. marketable tubers.
Second sprayed row on the east, 357 lbs. marketable tubers.
Average of the two sprayed rows, 315 lbs. marketable tubers.
Middle unsprayed row, 158 lbs. marketable tubers.

Yield per acre, sprayed, 134 bu. 36 lbs. marketable tubers.
Yield per acre, unsprayed, 67 bu. 28 lbs. marketable tubers.
Gain per acre, 67 bu. 8 lbs. marketable tubers.

The yield of culls was 25¾ bushels per acre on the sprayed and 29⅔ bushels on the unsprayed.

The loss from rot was somewhat greater on the unsprayed rows than on the sprayed, but it was not large in either case.

The sprayed rows yielded almost exactly twice as much as the unsprayed. However, it is somewhat doubtful if all of this remarkably large difference may be fairly attributed to spraying. Mr. Colyer thinks that the sprayed and unsprayed rows had practically the same chance, but in our judgment the unsprayed rows suffered somewhat more from bugs. They were treated once with dry paris green applied with a powder gun, while the sprayed rows received one application of paris green in bordeaux at the first spraying.

The items of expense of spraying fifteen acres four times in this experiment were as follows:

384 pounds copper sulphate, at 6c	$23 04
1½ barrels lime, at $1.35	2 03
26½ pounds paris green, at 14c	3 71
40 hours labor for team, at 25c	10 00
40 hours labor for man, at 15c	6 00
Wear on sprayer	1 00
Total	$45 78
Total cost of spraying per acre	$3 05
Cost per acre for each spraying	76¼

The market price of potatoes at digging time was 60 cents per bushel. Sixty-seven bushels of potatoes at 60 cents per bushel would be worth $40.20. Subtracting $3.05, the cost of spraying, there remains *a net profit of $37.15 per acre.*

THE MATTITUCK EXPERIMENT.

This experiment was conducted by W. H. Satterly at Mattituck in the eastern part of Long Island, 15 1-6 acres of potatoes being sprayed ten times. The potatoes were of the variety Green Mountain and in four lots. In one lot seven rows 657 feet long and three feet apart (⅓ acre) were left unsprayed for a check. The soil was a fertile sandy loam.

The spraying was done with a one-horse "Schanck" sprayer manufactured by John R. Shangle, Hightstown, N. J. This sprayer differs radically from all others used in these experiments. It has neither force pump nor nozzles. The liquid is drawn off by gravity onto two rapidly-revolving disks which break it into spray and at the same time scatter it over the plants in all directions. Six to eight rows are sprayed at each passage. (See Plate XIII, fig. 1.)

Bordeaux of the usual 6-4-50 formula was applied ten times at the rate of about 26 gallons per acre, on the following dates: First, June 13 and 14; second, June 21 and 23; third, June 28; fourth, July 4 and 5; fifth, July 9 and 11; sixth, July 16, 18 and 19; seventh, July 21 and 26; eighth, August 1 and 3; ninth, August 9 and 13; tenth, August 17. Paris green was applied with the bordeaux at the rate of about two pounds per acre whenever and wherever needed. Some portions of the field were treated oftener than others, but on an average three applications of poison were made. In all, 87 pounds of paris green were used.

The check rows were treated three times with paris green in lime water; namely, on June 14 and 28 and July 11.

The vines grew thriftily and soon covered the ground completely. The unsprayed rows were attacked by both early and late blight, flea-beetles and plant lice. The first three were largely controlled by spraying, but the plant lice, of course, were unaffected by it.

When the experiment was examined on July 20, early blight and flea-beetles were the leading enemies. Late blight, too, was becoming well established on the unsprayed rows and there were traces of it among the sprayed plants. The beneficial effect of the spraying was now just beginning to show. On crossing the field the unsprayed rows could be readily located by the poorer condition of their foliage.

By August 1, the unsprayed rows were badly blighted and by August 9 they were dead except for an occasional tuft of green leaves at the tips of a few plants here and there. On the latter date the sprayed plants on both sides of the unsprayed were but little injured. However, they were thoroughly infested with late blight and it was plain that they could not long survive if the weather conditions should become favorable to blight. Immediately after this there came a period of wet weather and the sprayed plants deteriorated rapidly. The last spraying was made on August 17 at which time the sprayed plants were still quite green.

The test rows were dug on September 8 with a potato digger. The yields were as follows:

Second sprayed row on the north, 889 lbs. marketable tubers.
Second sprayed row on the south, 765 lbs. marketable tubers.
Average of the two sprayed rows, 827 lbs. marketable tubers.
Middle unsprayed row, 788½ lbs. marketable tubers.

Yield per acre, sprayed, 304 *bu.* 36 *lbs. marketable tubers.*
Yield per acre, unsprayed, 290 *bu.* 26 *lbs. marketable tubers.*
Gain per acre, 14 *bu.* 10 *lbs. marketable tubers.*

The yield of culls was 31¼ bushels per acre for the sprayed and 47 bushels for the unsprayed.

Considering the striking difference in growth the difference in yield between the sprayed and unsprayed rows was surprisingly small. We confidently expected a gain of at least 50 bushels per acre here and should not have been at all surprised if it had been as much as 75 bushels per acre. The unsprayed rows were in plain view from a public road and the difference was so marked that the experiment attracted much attention. In some cases farmers came several miles to see it. The sprayed rows outlived

the unsprayed by at least two weeks; and all experience as well as carefully conducted experiments at the Vermont Station[29] go to show that the growth of tubers is rapid during the later growth of potato plants.

Thinking that there might have been some mistake somewhere, two other rows, one sprayed and the other unsprayed, were dug and weighed. The rows selected for this second trial were the second unsprayed row from the south and the fourth sprayed row on the south, so there were four rows between. The results were as follows:

Sprayed row 815 pounds, or 300 bushels 11 pounds marketable tubers per acre.

Unsprayed row, 751 pounds, or 276 bushels 37 pounds marketable tubers per acre.

Gain, 64 pounds, or 23 bushels 34 pounds marketable tubers per acre.

Although the second trial showed somewhat better results than the first one the gain was still smaller than it ought to have been. Probably there was no mistake in taking the yields, but we are satisfied that in some way the unsprayed rows had an advantage. Where the trouble lies it has been impossible to determine. Sprayed and unsprayed rows were of the same variety, planted and cultivated in the same way, on the same kind of soil and with the same amount of fertilizer so far as known. Mr. Satterly is unable to explain it. He was as much surprised as we were.

We are convinced, however, that Mr. Satterly's actual gain from spraying was more than 14 bushels per acre. The large average yield obtained supports this opinion. The total yield of marketable potatoes from 15½ acres was 4,838 bushels, which is at the rate of 312 bushels per acre. We do not believe that any unsprayed field of several acres on eastern Long Island gave an average yield as large as 300 bushels per acre in 1904.

The items of expense of spraying ten times in the Mattituck experiment are as follows:

479 pounds copper sulphate at 6 cents.............	$28 74
316 pounds lime at 1 cent	3 16

[29] Vermont Exp. Sta. Bul. 40:26; Ann. Rep. 12: 155–156; Bul. 72:4–5.

87 pounds paris green at 15 cents	$13 05
79 hours labor for man at 20 cents	15 80
38½ hours labor for boy at 10 cents	3 85
79 hours labor for horse at 10 cents	7 90
Repairs on sprayer	5 00
Total	$77 50
Total cost of spraying per acre	$5 11
Cost per acre for each spraying[30]	51

At 45 cents per bushel, the market price of potatoes at digging time, 14 bushels of potatoes would have a value of $6.30. Subtracting $5.11, the cost of spraying, there remains *a net profit of $1.19 per acre.*

SOUTHAMPTON EXPERIMENT NO. 1.

This experiment was conducted by H. A. Jagger at Southhampton in the eastern part of Long Island.[31] It included 14 acres of potatoes in three lots. Eight and one-half acres were sprayed 8 times and the remaining 5½ acres 6 times. In one of the lots sprayed 8 times and called the "experiment lot," three rows 622 feet long, 2 2-3 feet apart, were left unsprayed for a check. The soil was a sandy loam and the variety of potato Carman No. 1.

The spraying was done with the same outfit used in the experiment in 1903; namely a one-horse, home-made rig consisting

[30]The low expense of spraying in this experiment, 51 cents per acre, is partly due to the small quantity of bordeaux used and partly to the convenient facilities for making bordeaux as shown in Plate XIII, fig. 2. The mixing is done in barrels on two platforms placed one above the other stair fashion. The barrel with a shovel in it containes the stock lime. The other barrel, standing against the building, contains a stock solution of copper sulphate. The two barrels in front on the upper platform are "dilution" barrels, one for lime water, the other for copper sulphate solution. The two barrels on the lower platform are "mixing" barrels. By means of two short pieces of hose the contents of the two dilution barrels are drawn off simultaneously into one of the mixing barrels. From the mixing barrel the prepared mixture runs into the spray tank through another short piece of hose and while this is in progress the other mixing barrel is being filled so there is as little time wasted as possible. The water required comes from a tank in the barn, which is filled by means of a windmill. There is no dipping or lifting of water or bordeaux. The work is all done by gravity.

[31]For several years past Mr. Jagger has made a regular practice of spraying potatoes and believes that it is profitable. In 1903 he conducted a business experiment for the Station. A full account of this experiment is given in Bulletin 241, pp. 267–269.

of an Eclipse No. 2 pump mounted in a 100-gallon barrel on a two-wheeled cart.[32] One man did both the pumping and the driving.

The bordeaux used contained six pounds of blue vitriol to 50 gallons of water with sufficient lime added to satisfy the yellow-prussiate-of-potash test. Paris green was used freely with the bordeaux—at the rate of two pounds to 50 gallons in the first four sprayings. Altogether 110 pounds of paris green were used on the 14 acres which is at the rate of nearly eight pounds per acre. This is a considerably larger quantity per acre than was used in any of the other experiments except the Madrid experiment. The dates of spraying in the experiment lot were June 20, July 1, 8, 18, 25, 29, August 3 and 12.

The unsprayed rows were treated three times with paris green. Once, when the paris green was applied with a powder gun some of the plants received too much and the foliage was slightly injured.

In this experiment the chief enemy fought was late blight, *Phytophthora infestans,* which first appeared on the unsprayed rows about July 22 and soon after became so virulent that the unsprayed rows were entirely dead by August 10. On this date the sprayed portions of the field, although much superior to the unsprayed, were nevertheless, badly blighted. All unsprayed fields around Southampton were now dead with blight; but the sprayed fields, of which there were a good many, were still mostly green.

Flea-beetles, too, were considerable of a factor in the experiment and it was plain that spraying materially reduced their ravages although it did not wholly prevent them. There was also some early blight, *Alternaria solani,* which was more abundant on the unsprayed than on the sprayed rows.

The test rows were dug with a potato digger on September 6. The yield were as follows:

Second sprayed row on the west,[33] 675 lbs. of marketable tubers.
Middle unsprayed row, 474 lbs. of marketable tubers.

Yield per acre, sprayed, 295 *bu.* 25 *lbs. marketable tubers.*
Yield per acre, unsprayed, 207 *bu.* 27 *lbs. marketable tubers.*
Gain per acre, 87 *bu.* 58 *lbs. marketable tubers.*

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[32] For an illustration of Mr. Jagger's spraying outfit see Plate V, Bulletin 241.

[33] Owing to a misunderstanding, Mr. Jagger had already dug the second sprayed row on the east so that our usual method of taking the yield of the second sprayed row on either side could not be followed in this experiment.

The yield of culls was at the rate of 20 bushels per acre for the sprayed, and 28 bushels for the unsprayed.

The loss from rot was not measured but it was considerable and seemed to be fully as great on the sprayed as on the unsprayed.

It seems likely that in this experiment the difference of 88 bushels per acre shown by the test rows is greater than the actual gain due to spraying. Our reason for this opinion is the fact that the average yield of the field in which the test rows were located was far below that of the single sprayed row weighed. From a little over four acres only 900 bushels were sold making an average yield of less than 225 bushels per acre, while the sprayed row which was weighed yielded at the rate of 295 bushels per acre. Of course it is possible that the soil where the test rows were was better than the average and that the sprayed and unsprayed row had an equal chance in this respect, but so great a difference is to be regarded with suspicion at least. Had the yield of a sprayed row on the other side of the check rows been obtained, perhaps this uncertainty might have been cleared up. Mr. Jagger states that the sprayed row weighed, appeared to be the best one in the field, but he cannot explain why it should be so.

Although Mr. Jagger evidently did a fairly thorough job of spraying it is equally plain that still more thorough spraying was required to control the blight. It is in such violent cases as this that extra thorough work pays. We are confident that the kind of spraying done in the ten year experiment at Geneva would have produced double the gain obtained by Mr. Jagger.

The items of expense for spraying fourteen acres in this experiment are as follows:

656 pounds copper sulphate at 5¾c	$37 72
2 barrels lime at $1.35	2 70
110 pounds paris green at 14c	15 40
101 hours labor for man at 20c	20 20
101 hours labor for horse at 10c	10 10
Wear on sprayer	5 00
Total	$91 12

Total cost per acre for eight sprayings	$7 21
Cost per acre for each spraying	90

At 45 cents per bushel, the price at digging time, 88 bushels of potatoes would be worth $39.60. Subtracting $7.21, the cost of spraying per acre, there remains *a net profit of $32.39 per acre.*

SOUTHAMPTON EXPERIMENT NO. 2.

This experiment was conducted by Lewis E. Downs who sprayed 31 acres of potatoes eight times. The 31 acres were all of the variety Carman No. 1 and in five different lots. In one lot, three rows 1206 feet long, three feet apart, were left unsprayed.

The spraying was done with a "Watson" one-horse, four-row power sprayer like the one used in the Woodbury experiment. (See Plate XII, fig. 2.) As in the Woodbury experiment the sprayer was rigged with two nozzles per row although originally designed to carry but one. This change was necessitated by the rank growth of vines which covered the ground so completely that it was difficult to follow the rows. Under such conditions it is impossible to cover the foliage thoroughly with one nozzle per row. The bordeaux mixture was hauled into the field in a 450-gallon tank from which it was pumped into the spray tank as needed.

The dates of spraying in the field in which the experiment rows were located were as follows: June 30, July 1, 5, 9, 26, August 4, 6 and 13. Paris green was applied with the bordeaux three times, the total quantity used being 120 pounds, which is at the rate of four pounds per acre. On the unsprayed rows paris green was applied three times at the rate of two pounds per acre each time, making six pounds per acre in all. The dates of application were July 1, 5 and 26. In spite of the greater quantity of paris green used on the unsprayed rows bugs did slightly more damage here than on the sprayed rows. This supports the oft-repeated statement that bugs are more thoroughly controlled when the poison is applied with bordeaux than when the poison is used alone.

When we examined the experiment on July 22, there was no late blight to be found even on the unsprayed rows. Yet there was a marked contrast between the sprayed and unsprayed rows. The latter were of a darker green color and had been less injured by early blight, which was quite plentiful on unsprayed

rows. However, late blight must have appeared soon after July 22; for under date of August 6, Mr. Downs wrote that the unsprayed rows were badly blighted; and when we inspected the experiment on August 10, the unsprayed rows were dead, apparently having been killed by late blight. The sprayed rows adjacent still retained about three-fourths of their foliage, the other one-fourth having been ruined by late blight, early blight and flea-beetles, chiefly the first. At the same time Mr. Downs' other four sprayed fields were only moderately blighted while all unsprayed fields in the vicinity were dead. But it was a hard fight. It was necessary to spray between showers which were very frequent, often coming before the bordeaux had had a chance to dry on the foliage and then the work had to be repeated. Nevertheless, spraying proved highly profitable as will be shown presently.

The test rows were dug on October 8, with the following results:[34]

Second sprayed row on the east, 1686½ lbs. marketable tubers.
Second sprayed row on the west, 1646½ lbs. marketable tubers.
Average of the two sprayed rows, 1666½ lbs. marketable tubers.
Middle unsprayed row, 1203½ lbs. marketable tubers.

Yield per acre, sprayed, 334 bu. 24 lbs. marketable tubers.
Yield per acre, unsprayed, 241 bu. 30 lbs. marketable tubers.
Gain per acre, 92 bu. 54 lbs. of marketable tubers.

The yield of culls was 19½ bushels per acre for the sprayed and 18¼ bushels for the unsprayed.

On the test rows the loss from rot was inconsiderable, but in some other parts of the 31 acres a good deal of rot was found. Mr. Downs places the average loss from rot at about 50 bushels per acre. Notwithstanding this loss the total yield of marketable potatoes on the 31 acres was about 10,000 bushels or an average of 322 bushels per acre—a very good showing indeed.

The items of expense for spraying 31 acres eight times were as follows:

1705 pounds copper sulphate at 6c.	$102 30
5½ barrels lime at $1.35	7 43

[34] A noteworthy feature of this experiment is the close similarity of yield on the two sprayed rows, the difference being only 40 pounds on rows 73 rods long. In the Malone experiment (p. 124) the difference was even less, being only 5 pounds.

120 pounds paris green at 17c.	$20 40
16 days labor for man at $1.75	28 00
16 days labor for horse at $1.00	16 00
Carting bordeaux to the field	2 00
Wear on sprayer and bordeaux tank	15 00
Total	$191 13

Total cost of spraying per acre	$6 17
Cost per acre for each spraying	77

At 55 cents per bushel, the price at digging time, 93 bushels of potatoes would have a value of $51.15. Subtracting $6.17, the cost of spraying, there remains *a net profit of $44.98 per acre.*

SUMMARY OF BUSINESS EXPERIMENTS IN 1904.

The principal features of the fourteen business experiments are shown in the following table:

TABLE XI.—SHOWING RESULTS OF BUSINESS EXPERIMENTS.

EXPERIMENT.	Area sprayed.	No. of times sprayed.	Increase in yield per acre.	Total cost of spraying per acre.	Cost per acre for each spraying.	Net profit per acre.
	Acres.		*Bu.*			
Gainesville	26	4	74⅔	$3.19	$0 80	$28 92
West Henrietta	12	8	130	4 89	61	60 11
Spencerport	8½	6	21⅙	3 86	64	6 72
Clifton Springs	12	5	83⅓	4 62	92½	28 70
Denmark	2¾	4	21⅔	6 98	1 74½	3 85
Madrid	2⅔	4	35⅔	6 75	1 69	2 95
Malone	8	7	114¾	5 83	83⅓	40 07
Peru	16	4	—3¼	1 80	45	—2 94
Sliters	3	3	24½	4 92	1 64	5 12
Woodbury	14	7	107	5 32	76	58 90
Farmingdale	15	4	67	3 05	76¼	37 15
Mattituck	15⅙	10	14⅙	5 11	51	1 19
Southampton, No. 1	14	8	88	7 21	90	32 39
Southampton, No. 2	31	8	93	6 17	77	44 98

Total area sprayed in fourteen experiments, 180 acres.

Average increase in yield per acre, 62¼ bushels.[35]

[35] The average increase in yield per acre may be computed in two ways: *First,* by taking the sum of the figures in the column headed "Increase in yield per acre" and dividing by 14, the number of experiments; *second,* by finding the total increase in yield in each experiment (increase per acre multiplied by the number of acres), adding these totals together and dividing by 180, the total acreage.

The averages given are computed by the first method, which we regard as the better one for our purpose because the figures obtained by it show the average gain due to spraying in 14 different places without regard to

Average total cost of spraying per acre, $4.98.
Average cost per acre for each spraying, 93 cents.
Average net profit per acre, $24.86.

SUMMARY OF BUSINESS EXPERIMENTS IN 1903 [36]

Total area sprayed in six experiments, 61 1-6 acres.
Average increase in yield per acre, 57—bushels.
Average total cost of spraying per acre, $4.98.
Average cost per acre for each spraying, $1.07.
Average net profit per acre, $23.47.

VOLUNTEER EXPERIMENTS.

In one way or another the writers have learned of a considerable number of farmers who sprayed potatoes in 1904 and left a portion of the field unsprayed. These farmers were requested to measure the yield on sprayed and unsprayed rows and report the results to the Station together with an account of the method of spraying and other data pertaining to the experiment. About fifty reports were received, but a few of them were incomplete on some essential point. Forty-one are considered worthy of publication. Some of these experiments appear to have been very carefully conducted, while some others have been managed and reported somewhat carelessly. However, in every case, the figures given as the increase in yield due to spraying are based upon actual weight or measurement. No estimates are included.

These experiments are called "volunteer experiments" because the Station had nothing to do with them. They were planned and carried out entirely by the farmers themselves. The credit for them belongs to the farmers, not to the Station, and the writers wish here to thank all the gentlemen who have so kindly contributed information in regard to their experiments. Likewise, the blame for any inaccuracy in the published reports is

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the number of acres in each experiment. Computed by the second method the average increase in yield is 70+ bushels per acre. Likewise the average cost of spraying and the average net profit have been computed by the first method.

[36] It will be observed that these figures differ from those published in Bulletin 241, p. 283. This is in consequence of using a different method of computation as explained in the previous footnote. The figures given here have been obtained by the first method while those given in Bulletin 241 were obtained by the second method. In future bulletins the first method only will be used.

chargeable to those who conducted the experiments. In compiling the reports care has been taken to state the facts exactly as they were given to us. Moreover, each report was submitted, before publication, to the farmer furnishing it, for criticism and correction.

It is to be regretted that lack of space necessitates such close condensation of the reports as to make them tedious reading. In some cases it has been necessary to omit matter of considerable interest. The experiments are designated by numbers and taken up in the order of their location, commencing with those in the western part of the State and working east to Albany, after which come those located on Long Island.

EXPERIMENT NO. 1.

Conducted by George A. Kirkland, Dewittville, Chautauqua County. Two and three-fourths acres of potatoes, variety Lightning Express, were sprayed five times (July 6, 16, 30, August 15 and 29), with a one-horse, home-made rig covering two rows at each passage with two Vermorel nozzles per row. The pump used with an Eclipse No. 5 barrel spray pump. One man did both the pumping and the driving. The cost of materials for spraying was as follows:

150 pounds copper sulphate, at 6¾c.	$10 12
1 barrel lime	90
Total	$11 02

No record was kept of the labor.

Two rows 40 rods long, 3 feet apart, were left unsprayed. On September 3 these rows were entirely dead while the sprayed rows still had 75 per ct. of their foliage. The two unsprayed rows yielded 16¾ bushels or at the rate of 184¼ bushels per acre, while two sprayed rows adjacent yielded 19¼ bushels or at the rate of 211¾ bushels per acre which is a gain of 27½ bushels per acre.[37] There was no rot on the sprayed and only a little on the unsprayed rows.

Another portion of the same field was planted with Churchill Seedling, some rows of which were sprayed five times as above

[37] Unless otherwise stated, only marketable tubers are considered in these experiments.

while other rows were double-sprayed each time. A double-sprayed row outyielded an adjacent single-sprayed row by 66 bushels per acre, showing the importance of thorough spraying. This also tends to show, in the opinion of Mr. Kirkland, that, usually, less marked results are to be expected from spraying on early varieties than on late varieties, Lightning Express being an early, and Churchill Seedling a very late, variety.

Market price of potatoes at digging time, 50 to 55 cents.

EXPERIMENT NO. 2.

Conducted by F. T. Ransom of "Beaver Lodge," Ransomville, Niagara County. Twenty acres of potatoes were sprayed four times with a one-horse, home-made outfit operated by one man, spraying four rows at each passage with one nozzle per row. About fifteen acres constituted a day's work. The items of expense were as follows:

Labor for man and horse	$8 40
140 pounds copper sulphate at 4c	5 60
1 barrel lime	1 00
80 pounds paris green	11 20
Total	$26 30
Cost per acre for each spraying	$0 33

An unsprayed row 600 feet long, 30 inches wide, yielded 4½ bushels or at a rate of 130⅔ bushels per acre, while a sprayed row of the same length yielded 5¾ bushels or at the rate of 167 bushels per acre, which makes the gain due to spraying 36⅓ bushels per acre. The test rows were of the variety Early Sunrise.

The unsprayed rows were treated with paris green for bugs. They were affected by blight much earlier and more severely than were the sprayed rows. There was scarcely any rot on those sprayed; but on the unsprayed rows a little rot in some places.

For about three days after digging was begun potatoes sold in Buffalo and Niagara Falls at 85 cents per bushel, but the price soon dropped to 50 cents.

EXPERIMENT NO. 3.

Conducted by W. H. Grinnell, Albion. About two acres of potatoes, variety Sir Walter Raleigh, were sprayed four times with a two-horse outfit consisting of a barrel spray pump mounted on a two-wheeled cart with nozzles so arranged as to cover three rows at a time with three nozzles per row. One man drives while another works the pump. The total expense of spraying, including both labor and materials, was about $12.

One row 14½ rods long was left unsprayed. The bugs were kept off this row by hand picking so that they did but little damage. The yield was 62 pounds of marketable tubers and 38 pounds of culls. A sprayed row 20 feet distant yielded 144 pounds of marketable tubers and 32 pounds of culls. Thus the yield was at the rate of 62¾ bushels per acre for the unsprayed and 145¾ bushels per acre for the sprayed making a gain of 83 bushels per acre or 133 per ct. in favor of spraying. Mr. Grinnell thinks that the increased yield on the sprayed rows was chiefly due to their having been protected against flea-beetles which caused much havoc on the unsprayed row. The unsprayed row also blighted considerably more than the sprayed, but there was no rot on either sprayed or unsprayed. Price of potatoes at digging time, 60 cents.

EXPERIMENT NO. 4.

Conducted by C. W. Driggs, Elba, Genesee County. Ten acres of potatoes (Carman No. 3 and Rural New Yorker No. 2 mixed) were sprayed four times with a two-horse, four-row sprayer pump by hand. There was but one nozzle over each row. Generally, the outfit was operated by one man. In the last two sprayings the plants were sprayed twice in opposite directions, that is, double-sprayed.

Three rows 40 rods long were left unsprayed in a 4-acre field. One of these rows yielded 5 bushels (marketable and culls together) while an adjacent sprayed row yielded 6 bushels, the difference being at the rate of 22 bushels per acre—110 bushels per acre for the unsprayed and 132 bushels for the sprayed. The unsprayed rows died about ten days before the sprayed rows were killed by frost. There was very little rot anywhere

on sprayed or unsprayed rows. The unsprayed rows were slightly injured by bugs.

In another field of six acres two rows were sprayed about twice as much as the others, that is, 10 or 12 times, yet they blighted just as soon and there seemed to be no difference in yield. Mr. Driggs states that spraying seemed to have but little effect on blight at Elba the past season. Unsprayed fields generally appeared as good as sprayed ones. Market price of potatoes at digging time, 40 cents.

EXPERIMENT NO. 5.

Conducted by M. F. French, Gainesville, Wyoming County. One field of 6½ acres, variety White Giant, and another of five acres, variety Sir Walter Raleigh. Both fields were sprayed five times with a two-horse, home-made outfit carrying an Empire King barrel spray pump and rigged to spray four rows at a time with one nozzle per row. A man did the pumping and a boy the driving. The total cost of spraying 11½ acres was $36.40, including labor, chemicals, paris green and wear on sprayer.

In the 6½-acre field, four rows 60 rods long, 34 inches apart, were left unsprayed. These four rows yielded 38 bushels, or at the rate of 146 bushels 52 pounds per acre, while four sprayed rows adjacent yielded 50 bushels, or 193 bushels 15 pounds per acre, making a difference of 46 bushels 23 pounds per acre in favor of spraying.

In the 5-acre field, four rows 52 rods long were left unsprayed. They averaged 5 bushels per row or 89 bushels 36 pounds per acre, while four sprayed rows adjacent averaged eight bushels per row or 143 bushels 21 pounds per acre, making a difference of 53¾ bushels per acre in favor of spraying.

Averaging the results in the two experiments there is a gain of 50 bushels 4 pounds per acre due to spraying.

We had an opportunity to examine these experiments September 1. In the 6½-acre field the unsprayed rows were already half dead, while the sprayed rows were scarcely injured by blight. The sprayed plants outlived those unsprayed about two weeks.

In the five-acre field, also, there was considerable difference

between the sprayed and unsprayed rows, but the contrast was not as marked as in the other field. Here, there was much blight among the sprayed plants as well as the unsprayed.

In both fields the unsprayed rows were thoroughly treated four times with paris green by means of a powder gun so there was no damage by bugs. There was only a little rot, but there seemed to be quite as much on the sprayed rows as on those unsprayed. Price of potatoes, 45 cents.

EXPERIMENT NO. 6.

Conducted by C. W. Dusen, Gainesville. In a field of fifteen acres of potatoes, variety White Giant, different portions were sprayed two, three, four and five times respectively, and four rows 80 rods long, 32 inches apart, left unsprayed. The spraying was done with an outfit similar to the one used in Experiment No. 5.

The yields were as follows:

Four rows not sprayed, 43½ bu. or 134 bu. 31 lbs. per acre.
Four rows sprayed twice, 56 bu. or 173 bu. 11 lbs. per acre.
Four rows sprayed three times, 68 bu. or 210 bu. 17 lbs. per acre.
Four rows sprayed four times, 78 bu. or 241 bu. 13 lbs. per acre.
Four rows sprayed five times, 92 bu. or 284 bu. 31 lbs. per acre.

The difference of 38 2-3 bushels per acre between unsprayed rows and rows sprayed twice may be fairly considered due to spraying since the twice-sprayed rows were adjacent to the unsprayed rows; likewise, the gain of 75 bushels 46 pounds per acre in favor of three sprayings may be justly attributed to the spraying since these rows adjoined the unsprayed rows on the other side. But the rows sprayed four times were at considerable distance from the unsprayed rows and so cannot be closely compared with them. Neither can the five-sprayed rows, for they were still farther away and on soil which had been fertilized more heavily. However, it is probable that the greater part of the large increase in yield on these rows is due to the spraying.

Market price of potatoes at digging time, 45 cents per bushel.

EXPERIMENT NO. 7.

Conducted by L. H. Taylor, Hardys, Wyoming County. Five acres of potatoes, Carman No. 3, sprayed four times with an Empire King barrel spray pump mounted on a two-wheeled, one-

horse cart rigged to spray four rows at a time with one nozzle per row. One man did both pumping and driving. The dates of spraying were July 13, 23, August 12 and 23. The expense was $5.12 for copper sulphate and prepared lime besides about two days' work for one man and horse.

Five rows 75 rods long, 34 inches apart, were left unsprayed. These rows yielded 46 bushels of marketable tubers and 7½ bushels small ones. Five sprayed rows (three on one side of the unsprayed and two on the other) yielded 67 bushels marketable tubers and 6½ bushels small ones. These yields are at the rate of 114 bushels per acre for the unsprayed and 166 bushels for the sprayed, making a gain of 52 bushels per acre in favor of spraying.

The unsprayed rows commenced to blight August 20 and all died in a short time. The sprayed rows did not show much blight until September 15 and were still quite green when killed by frost September 22. The contrast in appearance between sprayed and unsprayed rows was very marked. There was very little rot. The unsprayed rows were not injured by bugs. Price of potatoes, 40 cents.

EXPERIMENT NO. 8.

Conducted by L. J. Wilson, Castile, Wyoming County. Eight acres of potatoes, planted June 14, were sprayed four times with an Empire King barrel spray pump mounted in a fifty-gallon cask on a one-horse, two-wheeled cart so rigged as to cover four rows at each passage with one nozzle per row. Three rows 4½ rods long, three feet apart, were left unsprayed.

The middle unsprayed row yielded 388 lbs. or at the rate of 139 bu. 21 lbs. per acre while the second sprayed row on one side yielded 461 lbs. or 165 bu. 34 lbs. per acre. Therefore, spraying increased the yield by 26 bu. 13 lbs. per acre. There was no rot worth mentioning on the sprayed or unsprayed rows. The benefit of spraying would have been more marked had the potatoes been planted earlier or frost come later. As it was, the sprayed plants were in full foliage when killed by frost September 22. The unsprayed rows were pronounced dead from blight about two days earlier. This was Mr. Wilson's first experience spraying potatoes.

Market price of potatoes at digging time, 45 cents per bushel.

EXPERIMENT NO. 9.

Conducted by Thomas Beaumont, Castile. Eleven acres of potatoes, Rural New Yorker No. 2, were sprayed five times with the same kind of an outfit as that used in Experiment No. 8. It was operated by two men, one to drive and one to pump. Four rows 50 rods long, 33 inches apart, were left unsprayed for a check. The copper sulphate used cost six dollars and the lime one dollar.

One of the unsprayed rows yielded 420 pounds, which is at the rate of 133¾ bushels per acre; while a sprayed row, only one row distant from the unsprayed row, yielded 496 pounds or 158 bushels per acre. This shows that spraying increased the yield at the rate of 24¼ bushels per acre. There was no rot.

Although not injured by bugs, the unsprayed rows died about two weeks before the sprayed rows (still in full foliage) were killed by frost. No poison was used on either sprayed or unsprayed plants. Owing to continued wet weather in the spring, planting was delayed until June 15. Had the sprayed plants been able to complete their growth the increase in yield due to spraying would certainly have been greater. Mr. Beaumont had never sprayed potatoes before.

Market price of potatoes at digging time, 45 cents.

EXPERIMENT NO. 10.

Conducted by S. H. Cridler, Hornellsville. Nine and one-fourth acres of potatoes, variety Carman No. 3, were sprayed three times with an Aspinwall automatic four-row sprayer commencing about July 10 and repeating at intervals of two weeks. Four rows, 40 rods along, 34 inches apart, through the center of the field, were left unsprayed. The total cost of spraying was $1.52 per acre, including labor.

One unsprayed row yielded 11 bushels or 256 bushels 18 pounds per acre, while a sprayed row nearby yielded 12 bushels or 279 bushels 36 pounds per acre, making the gain due to spraying 23¼ bushels per acre. There was no trouble from bugs or rot. Mr. Cridler's average yield was 230 bushels per acre.

These potatoes were planted May 20, yet when frost came they were as green as ever except the four unsprayed rows which were partly dead and in some places entirely dead. The sprayed plants

were darker green and more vigorous than the unsprayed. As in the two previous experiments the gain from spraying was lessened by the frost.

Mr. Cridler expresses the opinion that it pays to spray potatoes, the oftener the better.

The market price of potatoes at digging time was 40 cents per bushel.

EXPERIMENT NO. 11.

Conducted by J. E. Schenck, Jasper, Steuben County. Two and one-fourth acres of potatoes, variety Sir Walter Raleigh, were sprayed four times with a four-gallon compressed-air sprayer. One row 50 rods long was left unsprayed.

The unsprayed row yielded 7 bushels, which is at the rate of 126 bushels per acre; while the sprayed row next to it yielded 9 bushels, or at the rate of 162 bushels per acre, making a difference of 36 bushels per acre in favor of spraying. There was no rot of importance even on the unsprayed rows and there was no damage by bugs.

The unsprayed row had just begun to show the effects of blight when the plants were killed by the early frost of September 22. The fourth spraying was made only five days before this frost, consequently could not have done any good. The increased yield on the sprayed row should be credited to three sprayings instead of four.

Price of potatoes at digging time, 35 cents.

EXPERIMENT NO. 12.

Conducted by M. C. Hollenbeck, Jasper. About two acres of potatoes were sprayed once with a five-gallon compressed-air sprayer. Two rows 27 rods long, three feet apart, were left unsprayed for comparison. At digging time the two unsprayed rows yielded 12 bushels, or at the rate of 195 bushels 32 pounds per acre, while two sprayed rows nearby yielded 14 bushels, or at the rate of 228 bushels 8 pounds per acre. Therefore, the gain due to spraying was at the rate of 32 bushels 36 pounds per acre.

As the potatoes were late-planted they were still growing when frost came on September 22. Although the unsprayed rows were not injured by bugs they were much inferior to the sprayed rows in appearance of the foliage. There was but little rot.

The market price of potatoes at digging-time was 35 cents per bushel.

EXPERIMENT NO. 13.

Conducted by C. Zimmerman, Adams Basin, Monroe County. Five acres of potatoes, variety Carman No. 3, were double-sprayed four times with a New Victor two-horse potato sprayer covering five rows at a time with one nozzle per row. About 2,000 gallons of bordeaux were used and the total expense of the spraying was $35.90, the items being as follows:

40 pounds copper sulphate at 6 cents	$14 40
Lime	90
40 pounds paris green at 14 cents	5 60
4 days' labor, man and team, at $3.75	15 00
Total	$35 90
Total cost of spraying per acre	$7 18

Five rows 34 rods long were left unsprayed. Two of these rows yielded 15 1-3 bushels or at the rate of 198 bushels 25 pounds per acre, while two sprayed rows nearby yielded 18 2-3 bushels or at the rate of 241 bushels 33 pounds per acre, making the gain from spraying 43 bushels 8 pounds per acre.

The unsprayed rows blighted about a month earlier than the sprayed. The loss from rot was practically the same on the sprayed and unsprayed rows, being estimated at 2 per ct. in each case. The unsprayed rows were not injured by bugs. Market prices of potatoes, 50 cents.

EXPERIMENT NO. 14.

Conducted by Rufus A. Babcock, Spencerport, Monroe County. Eighteen acres of potatoes, variety Dooley, were sprayed five times with a one-horse home-made rig carrying a Deming barrel spray pump and rigged to spray four rows at a time with one nozzle per row. It was operated by one man who could spray the entire 18 acres in one day. The items of expense were as follows:

305 pounds copper sulphate at 6 cents	$18 30
510 pounds of lime	4 60

30 pounds paris green at 18⅓ cts	$5 50
5 days' labor for man and horse at $2.25	11 25
Wear on sprayer	3 00
Total	$42 65

There were left unsprayed 12 short rows having an area of 42 square rods, or a little more than one-fourth acre. These rows yielded 35 bushels of marketable tubers and 6 bushels of small and rotten ones. Twelve sprayed rows of the same length, and adjacent, yielded 43 bushels marketable tubers and 2 bushels small ones. These yields are at the rate of 133⅓ bushels per acre for the unsprayed and 163 5-6 bushels for the sprayed, making a difference of 30½ bushels per acre in favor of spraying.

The unsprayed rows were not injured by bugs but they were dead before frost came while the rest of the field was quite green when killed by frost September 22. A good many rotten tubers were found on the unsprayed rows but none on the sprayed. Mr. Babcock sold a large part of his crop for seed at 50 cents per bushel.

EXPERIMENT NO. 15.

Frank Dobson of Charlotte, seven miles north of Rochester, sprayed 4½ acres of potatoes in two lots. A part of the potatoes were in an apple orchard where three rows were left unsprayed. The others were in a young raspberry plantation, the raspberries being in rows five feet apart with potatoes planted between. In this case one row was left unsprayed. In the orchard the variety of potato was Michigan Snowflake, planted June 16; in the raspberry plantation, Rural New Yorker No. 2, planted June 20.

The spraying was done with a home-made rig consisting of a one-horse two-wheeled cart, a fifty-gallon barrel with a Planet double-acting spray pump and two leads of hose.[38] Three men were required to operate it—one on the cart to pump and drive and two others on the ground to direct the spray nozzles. The dates of spraying were August 11, 23 and September 2.

[38] An illustration of Mr. Dobson's outfit is shown in Bulletin 241 of this Station, Plate IX.

In the orchard the yields were as follows:

120 hills sprayed, 176 lbs., equal to 170 bu. 22 lbs. per acre.
120 hills unsprayed,[39] 116 lbs., equal to 112 bu. 17 lbs. per acre.
Gain from spraying, 60 lbs., equal to 58 bu. 5 lbs. per acre.

In the raspberry plantation the yields was as follows:

100 hills sprayed, 175 lbs., equal to 188 bu. 13 lbs. per acre.
100 hills unsprayed, 123 lbs., equal to 132 bu. 17 lbs. per acre.

Gain from spraying, 52 lbs., equal to 55 bu. 56 lbs. per acre.

Averaging the results obtained in the two experiments *the gain due to spraying is 57 bushels per acre.*

In the raspberry plantation, blight was kept completely under control, but in the orchard there was some blight among the sprayed plants. Nevertheless, the sprayed plants here outlived the unsprayed by more than two weeks and the difference would have been still greater had not the sprayed plants been killed by frost. The unsprayed rows were not injured by bugs, and there was but little rot anywhere.

Mr. Dobson believes that the secret of success in spraying potatoes is in commencing before the blight appears and doing the work thoroughly.

The market price of potatoes at digging time was 65 cents.

EXPERIMENT NO. 16.

Conducted by D. S. Norris, West Rush, 12 miles south of Rochester. Four and one-half acres of potatoes, Carman No. 3, were sprayed eight times using in all 29 barrels of bordeaux mixture. The dates of spraying were July 16, 25, 29, August 6, 13, 17, 27, and September 3. In the center of the field four rows 31½ rods long, three feet apart, were left unsprayed.

The spraying was done with a home-made outfit covering four rows at a time with one Vermorel nozzle per row. The wheels were taken from an old grain drill; pitman and crank from an old binder; pressure gauge, relief valve, sprockets and chain purchased for the purpose. All the parts together, excepting the pump, did not cost to exceed $10. The pump was an E. C.

[39] In the orchard, the test hills were taken from the middle unsprayed row and the second sprayed row; in the raspberry plantation, from adjacent rows separated by a row of raspberries.

Brown Siphonette purchased for use in the orchard. The sprayer was run at a pressure of 50 to 75 pounds.

The soil being rich and well cultivated the vines grew very rank. Consequently, blight was severe. On August 6 the unsprayed rows were showing signs of blight and by August 27 they were entirely dead. On the latter date the whole field was showing some blight but the unsprayed rows were in so much worse condition than the sprayed that from a distance it looked as if there was a road across the field. (See Plate XIV, fig 1.)

The four unsprayed rows yielded 15 bushels of marketable tubers and 5 bushels of small ones; while the four sprayed rows next to them yielded 40 bushels of marketable tubers, 3 bushels of small ones and 2 bushels of sunburned tubers. These yields are at the rate of 270 bushels 54 pounds per acre for the sprayed plants and 74½ bushels for those unsprayed, making *the gain due to spraying* 196 *bushels* 24 *pounds of marketable tubers per acre.* In reality the gain was greater than this. The two bushels of sunburned tubers were of marketable size and should be credited to the sprayed rows because it was no fault of the spraying that they were sunburned. The potatoes had been planted shallow and no hilling done. If we class the sunburned tubers as marketable the gain due to spraying was at the rate of 210 bushels per acre. With the exception of the ten-year experiment at Geneva, where the gain was at the rate of 233 bushels per acre (See page 100), no other experiment in 1904 gave as large returns for spraying. There is good reason to believe that practically all the increased yield on the sprayed rows was due to spraying. Bugs probably injured the unsprayed rows slightly more than the sprayed, but if so the difference must be credited to the bordeaux as no poison was used on either the sprayed or unsprayed. There was but little rot on either the sprayed or unsprayed rows.

The items of expense were as follows:

158 pounds copper sulphate at 6½ cents	$10 27
Lime	1 00
41 hours labor for man and horse at 25 cents	10 25
Wear on sprayer	2 00
Total	$23 52

Price of potatoes at digging time, 40 to 45 cents.

EXPERIMENT NO. 17.

Conducted by T. E. Martin, West Rush. In a field of 18 acres of potatoes, variety Sir Walter Raleigh, 17 acres were sprayed and one acre (18 rows), about the center of the field, left unsprayed. Between July 11 and September 20 the sprayed portion of the field received frequent light applications[40] of bordeaux, the total quantity used being 178 barrels. The sprayer used was a one-horse, six-row, homemade outfit,[41] the same one used by Mr. Martin in his experiment in 1903. (See Bulletin 241, p. 279 and Plate VIII.)

The items of expense were as follows:

900 pounds copper sulphate at 5¾ cents (less 1% discount for cash)	$51 23
140 pounds copper sulphate at 6 cents	8 40
Freight on 140 pounds copper sulphate	40
50 pounds paris green at 15 cents (less 1% discount for cash)	7 43
11 bushels lime at 25 cents	2 75
15 days labor for man and horse at $3	45 00
Wear on sprayer, repairs, etc	15 00
Total	$130 21
Total cost of spraying per acre	$7 66

The 17 acres sprayed yielded 4,875 bushels of marketable potatoes, or at the rate of 287 bushels per acre, while the unsprayed acre yielded only 225 bushels, making the gain due to spraying 62 bushels per acre. The greater part of the crop was sold at digging time or soon after at prices ranging from 40 to 50 cents per bushel.

The writers visited this experiment twice. On September 9 the contrast between sprayed and unsprayed areas was marked. There was no evidence that the unsprayed rows had been injured by bugs. Early blight was plentiful on the unsprayed, and this seems to have been the chief enemy, although it is likely that late blight, too, caused considerable injury during August.

[40] The exact number of sprayings cannot be stated.
[41] With one Bordeaux nozzle over each row.

On September 22 the plants on the unsprayed acre were all dead except for small tufts of green leaves on a few plants at the north end of the field. The sprayed plants still retained a large part of their foliage, but they were showing old age[42] and were somewhat injured by early blight. This latter fact is noteworthy because the spraying in this experiment was of the most thorough kind and should have controlled early blight absolutely were it possible to do so. Plate XIV, fig. 2, shows the condition of the field on September 22. The plants were killed by frost on the following night.

Notwithstanding the large number of sprayings in this experiment, the actual expense was not large, being only $7.66 per acre. At 42½ cents per bushel for potatoes there was a net profit of $18.69 per acre on the operation.

Mr. Martin has practiced spraying potatoes for several years past and is convinced that it is profitable.

EXPERIMENT NO. 18.

Conducted by John Dell, East Rush. Twelve acres of potatoes, variety Rural New Yorker No. 2, were sprayed four times, with six rows 870 feet long, 34 inches apart, left unsprayed for a check.

The spraying was done by a hired operator and machine, at 45 cents per acre for each application, or $1.80 per acre for the four applications. This includes both labor and chemicals. The sprayer used was a one-horse automatic Hudson sprayer, which sprays six rows at each passage with one nozzle per row.

The middle four unsprayed rows yielded 31 bushels, or at the rate of 136 bushels 38 pounds per acre; while four sprayed rows separated from them only by one sprayed and one unsprayed row, yielded 39 bushels, or at the rate of 172 bushels 17 pounds per acre. Thus the gain due to spraying was 35⅔ bushels per acre.

Neither sprayed nor unsprayed rows were injured by bugs. In each 100 bushels there were about three bushels of rotten tubers. The unsprayed rows died about three weeks earlier than the sprayed, making a very striking contrast. Price of potatoes in Rochester at digging time, 65 cents per bushel.

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[42] The potatoes were planted May 18.

EXPERIMENT NO. 19.

Conducted by George C. Schoen, Pittsford. Fifteen acres of potatoes, variety Peerless Junior, were sprayed four times with an automatic, one-horse sprayer called the "New Model Aroostook Six-Row Sprayer." It carries one nozzle per row. Three rows 70 rods long, 35 inches apart, were left unsprayed. The total expense for spraying materials was $1.80 per acre.

The unsprayed rows blighted much more than those sprayed, making the contrast in appearance of the foliage very marked. No damage was done by bugs.

The yield of the middle unsprayed row was 11 bushels, or at the rate of 142 bushels 13 pounds per acre, while the first sprayed row, only six feet away, yielded 18 bushels, or at the rate of 232 bushels 44 pounds per acre. Therefore, the gain due to spraying was 90½ bushels per acre. The total yield of the fifteen acres was 3,510 bushels, or an average of 234 bushels per acre.

The market price of potatoes at digging time was 40 cents per bushel.

EXPERIMENT NO. 20.

Conducted by Roy W. Battams, Fishers, Ontario County. Twenty-four acres of potatoes were sprayed, a part twice and the remainder three times. Four rows were left unsprayed. The sprayer used was homemade, four-row outfit, hauled by two horses and operated by two men—one to pump, the other to drive. The spray pump was a Gould's Pomona. There was one Vermorel nozzle for each row. The cost of spraying was about $1.03 per acre each time, the items being as follows: Copper sulphate, 40 cents; prepared lime, 9 cents; paris green, 24 cents; and labor 30 cents.

An unsprayed row 30 rods long, 34 inches wide, yielded 7½ bushels, or at the rate of 233 bushels per acre; a twice-sprayed row, four rows away, yielded 8¼ bushels, or at the rate of 256⅓ bushels per acre; and a three-sprayed row, eight rows away, yielded 9½ bushels, or at the rate of 295 bushels per acre. That is to say, two sprayings increased the yield 23⅓ bushels per acre, while three sprayings increased it 62 bushels per acre. The test rows were of the variety Pride of Britain. The third spraying, made August 3, seems to have been much more effective than the

earlier ones. Another field of eight acres given a single application on this date did not blight at all.

Mr. Battams is of the opinion that one or two more sprayings following the third one would have been highly profitable, but at the time he feared that further spraying would do more harm than good owing to the breaking of the large vines by driving through them. He regards spraying as an essential factor in the production of large crops.

When the unsprayed rows died the twice-sprayed rows were only half-dead and the three-sprayed rows were still in full foliage. The latter outlived the unsprayed rows by three weeks. There was no rot and the unsprayed rows were not injured by bugs. Market price of potatoes at digging time, 45 cents.

EXPERIMENT NO. 21.

Conducted by Charles E. Green, Victor, Ontario County. Mr. Green sprayed fourteen acres of potatoes eight times between July 15 and September 1. The work was done with a home-made outfit consisting of a two-wheeled cart carrying a Spramotor spray pump mounted in a barrel and rigged to cover four rows at a time with one Vermorel nozzle per row. The outfit was drawn by one horse, and one man dd both pumping and driving.

One acre of the potatoes was in a young pear orchard set in the spring of 1904. Between the rows of trees there were eight strips of potatoes of four rows each and these were sprayed. Potatoes were planted also in the rows with the trees and these were not sprayed. Accordingly, there were 32 sprayed rows and eight unsprayed rows in the orchard.

At digging time the yield on the sprayed and unsprayed rows was measured. Making due allowance for space occupied by the trees in the unsprayed rows, the yield was at the rate of 130 bushels per acre, while the sprayed rows yielded at the rate of 200 bushels per acre. Thus the gain from spraying was 70 bushels per acre.

The difference in growth was remarkable. The sprayed rows were finally killed by frost October 15 after having outlived the unsprayed rows about five weeks. There was but little rot on either the sprayed or unsprayed. Price of potatoes, 40 cents.

EXPERIMENT NO. 22.

H. Van Voorhis, Hopewell, Ontario County, sprayed fifteen acres of potatoes five times, leaving unsprayed three rows of Sir Walter Raleigh 45 rods long.

The sprayer used was a two-horse, home-made outfit covering six rows at a time with one Vermorel nozzle per row. The pumping was done by power obtained from the wheels.

The yield of the middle unsprayed row was 7 bushels, or at the rate of 136 bushels 51 pounds per acre. The first sprayed row, only six feet away, yielded 10½ bushels, or at the rate of 205 bushels 16 pounds per acre. This makes the gain from spraying 68 bushels 25 pounds per acre.

We examined this experiment on August 23 and again on September 9. At the time of our first visit it was easy to pick out the unsprayed rows at a short distance. They had already lost a good many of their lower leaves from late blight while the sprayed rows showed only a little blight. Also the sprayed rows were noticeably of a darker green color. On September 9 the unsprayed rows were nearly dead while the sprayed rows adjacent, although showing considerable brown foliage, were still in fair condition. Probably two-thirds of their foliage was green.

The fifth spraying was made September 5 and 6 about three weeks after the fourth spraying. Much better results would have been obtained if an extra spraying had been made about August 26. Mr. Van Vooris is convinced of the necessity of thorough spraying.

Bugs did no damage to the unsprayed rows and there was no rot worth mentioning on either sprayed or unsprayed. Price of potatoes, 40 cents.

EXPERIMENT NO. 23.

This experiment was made by Ed. Welch, Phelps, Ontario County. He sprayed five acres of potatoes, Carman No. 3, twice, the last application being a double one. Two rows 1006 feet long were left unsprayed.

The spraying was done with a two-horse, five-row Aroostook power sprayer, the same one used by Mr. Welch in his experiment in 1903. (See Bulletin 241, page 276.) The total expense of spraying was $7.30.

An unsprayed row yielded 1271 pounds, at the rate of 305⅔ bushels per acre, while a sprayed row next to it yielded 1316 pounds, or at the rate of 316½ bushels per acre, making a difference of only 10 5-6 bushels per acre in favor of spraying. This is the least gain of any in the 41 volunteer experiments. The explantation of it is that there was no blight.

Fortunately, we had the opportunity of watching this experiment. Throughout the whole season, the plants, unsprayed as well as sprayed, remained entirely free from blight, but why this should be so is not clear. The vines grew large, completely covering the ground and the soil was moderately heavy, being a sandy loam with some gravel in it. Neither was the location unfavorable to blight and several other fields in the vicinity blighted badly. But whatever the cause it is a fact that blight was absent from this field. Bugs, too, were almost entirely absent although no poison was used. No damage was done by flea-beetles.

By September 7 it was noticeable that the unsprayed rows were not as dark green in color as the sprayed rows next to them. This difference in color gradually became more pronounced. Finally, by September 19 the unsprayed rows began to turn brown and die earlier than the sprayed and then the unsprayed rows could be easily traced clear across the field by the difference in color. As there seemed to be no blight it is not easy to explain why the unsprayed rows should die first, but such was the case.

The results of this experiment tend to support the theory that spraying may be beneficial even when there is no blight or insects to fight. It appears that bordeaux mixture has a stimulating effect on potato foliage.

The market price of potatoes at digging time was 40 cents.

EXPERIMENT NO. 24.

Conducted by J. V. Salisbury & Sons, north of Phelps. In this experiment seven acres of potatoes (Rural New Yorker No. 2 and Carman No. 3 mixed) were sprayed four times with a two-horse, Aroostook power sprayer covering six rows at a time with one Vermorel nozzle per row. This is the same sprayer used in their experiments in 1903. (See Bulletin 241, pages 269 to 276,

and Plate VI.) The total expense of spraying was $21.50. Three rows 850 feet long were left unsprayed.

The middle unsprayed row yielded 365 pounds or 103 bushels 54 pounds per acre, while the second sprayed row (only two rows between) yielded 508 pounds or 144 bushels 37 pounds per acre, which makes the gain due to spraying 40 bushels 43 pounds per acre.

Bugs were not troublesome. The few that appeared on the unsprayed rows were removed by hand picking so that they did no harm. On the sprayed rows they were poisoned with arsenite of soda applied with the bordeaux. There was no rot. The unsprayed rows were severely attacked by late blight and died from seven to ten days earlier than those sprayed. Price of potatoes at digging time, 40 cents.

EXPERIMENT NO. 25.

This experiment, also, was conducted by J. V. Salisbury & Sons, on their farm east of Phelps. Fifteen acres of potatoes were sprayed five times with the same sprayer used in Experiment No. 24. Three rows 1140 feet long were left unsprayed. The unsprayed rows and adjacent sprayed rows were of the varieties Rural New Yorker No. 2 and Carman No. 3 mixed. Accurate record of the expense of spraying in this field was not kept, but judging from accounts kept in 1903 and in Experiment No. 24 the expense was probably 80 cents per acre for each spraying or $60 for spraying 15 acres five times.

The middle unsprayed row yielded 593 pounds, or at the rate of 125 bushels 49 pounds per acre, and the yield of the second sprayed row on one side of the unsprayed was 907 pounds or 192 bushels 26 pounds per acre. Thus the gain from spraying was 66 bushels 37 pounds per acre, or nearly 53 per ct.

The unsprayed rows were treated once with paris green, which was sufficient to control bugs; while on the sprayed rows arsenite of soda was used with the bordeaux. There was no rot on sprayed or unsprayed rows. Price of potatoes 40 cents.

The soil in the western part of this field was clay loam while in the eastern portion it was quite sandy. Consequently, blight was much more virulent toward the west. Here, the sprayed rows outlived the unsprayed by at least two weeks. Practically

all of the blight was late blight, *Phytophthora infestans.* The Messrs. Salisbury are enthusiastic advocates of spraying.

EXPERIMENT NO. 26.[43]

D. Lyon, of Phelps, engaged J. V. Salisbury & Sons to spray his ten-acre field of potatoes at $1.00 per acre for each application. The Messrs. Salisbury were to furnish everything and use their judgment as to the proper number of sprayings and the time of making them. Four sprayings were made, the last one on August 22. Therefore, the total expense of the spraying was $40. The spraying was done with the same outfit used in Experiments No. 24 and No. 25. There being very few bugs it was unnecessary to use any poison on either the sprayed or unsprayed plants.

Three rows 715 feet long and of the variety Rural New Yorker No. 2, were left unsprayed. On August 22 late blight was already plentiful on the unsprayed rows and by September 7 there was a marked contrast between the sprayed and unsprayed rows clear across the field. The foliage on the unsprayed rows was scant and of lighter green color than on the sprayed. On September 19 the unsprayed rows were nearly but not quite dead throughout their entire length, while the sprayed rows on both sides of them were still in good condition.

As a consequence of so much difference in growth there was a marked difference in yield as follows:

Middle unsprayed row, 326 lbs., or 110 bu. 18 lbs. per acre.
Second sprayed row, 611 lbs., or 206 bu. 43 lbs. per acre.
Gain from spraying, 285 lbs., or 96 bu. 25 lbs. per acre.

The total yield on the ten acres was 2200 bushels of marketable tubers or at the rate of 220 bushels per acre. Price of potatoes, 40 cents.

For the owner of the potatoes, the spraying was certainly very profitable. At a total expense of only $40 his crop was increased by 964 bushels worth $385.60.

EXPERIMENT NO. 27.

Conducted by H. W. Hadlow, Geneva. A garden patch containing about one-fourth acre of potatoes, variety Rural New Yorker No. 2, was sprayed six times very thoroughly with a

[43] Reported by J. V. Salisbury & Sons.

knapsack sprayer. The first spraying was made July 4 and the last one August 15. One row 170 feet long was left unsprayed.

This experiment was located near the Experiment Station where the writers had opportunity to watch it closely. There was a rank growth of vines which completely covered the ground early in the season. By August 15 only a few green leaves were left on the unsprayed row, all the others having been killed by late blight, *Phytophthora infestans*. At the same time the sprayed rows were perfect.

On August 23 the rows were photographed (See Plate XV). At this time most of the plants on the unsprayed row were not only dead but their stalks were dry and shriveled. Sprayed plants on both sides were in full foliage showing only traces of blight. By September 9 the sprayed plants were commencing to die, apparently of old age, and by September 15 were dead after having outlived the unsprayed plants by a whole month. Aside from the ten-year experiment at the Station the past season, this experiment of Mr. Hadlow's was the most striking demonstration of the value of spraying that we have ever seen. It should convince the most skeptical that spraying, properly done, will prevent blight.

At digging time, Mr. Hadlow, assisted by the writers, weighed the potatoes from the unsprayed row and from the adjacent sprayed row on either side with the following results:

West sprayed row, 161½ pounds of marketable tubers.
East sprayed row, 266 pounds of marketable tubers.
Average of sprayed rows, 213¾ lbs., or 304 bu. 14 lbs. per acre.
Middle unsprayed row, 104 lbs., or 148 bu. 2 lbs. per acre.
Gain from spraying, 109¾ lbs., or 156 bu. 12 lbs. per acre.

The gain of over 100 per ct. was almost wholly due to preventing the ravages of late blight and the rot which follows it. There was no other disease or insect enemy of importance. The unsprayed rows were not injured by bugs. There appears to have been considerably more rot on the unsprayed row than on the sprayed. It was impossible to determine accurately the amount of rot on the unsprayed row because the affected tubers were in an advanced stage of decay. On the sprayed rows there was only an occasional rotten tuber.

It is not known why there was such a wide difference in yield between the two sprayed rows measured. The vines grew equally well on the two rows and gave no hint of any difference.

The potatoes were dug in small quantities at different times and sold as dug at prices ranging from 40 to 75 cents, the average price being 50 cents per bushel.

EXPERIMENT NO. 28.

Conducted by F. C. & L. B. Bradley, Interlaken, Seneca County. About five and one-quarter acres of potatoes, Carman No. 3, were sprayed four times with a two-horse, home-made outfit consisting of a spray pump mounted in a barrel on a two-wheeled cart and arranged to spray four rows at a time with one nozzle per row. Two men were required to operate it—one to pump and one to drive. The last three sprayings were double sprayings, that is the plants were sprayed twice each time in opposite directions.

The items of expense were as follows:

218 pounds copper sulphate at $6\frac{2}{3}$c	$14 54
1 barrel lime	1 75
1 ounce yellow prussiate of potash	10
Paris green	1 50
Labor for two men and team	21 00
Total	$38 89

One row $47\frac{2}{3}$ rods long was left unsprayed. This row yielded $7\frac{4}{5}$ bushels, or at the rate of 144 bushels 4 pounds per acre while the two adjacent sprayed rows, one on either side, averaged $11\frac{1}{3}$ bushels or at the rate of 206 bushels 52 pounds per acre. Thus the gain from spraying was 62 bushels 48 pounds per acre.

Most of this gain is due to the prevention of the ravages of blight and flea-beetles, but the unsprayed row suffered somewhat more from bugs although poison was applied to it as many times as on the sprayed rows. About two-thirds of the unsprayed row blighted badly and turned brown while the sprayed rows adjacent were dark green. There was but little rot. Price of potatoes, 35 cents.

This was the first experience of the Messrs. Bradley with spraying potatoes, but they are well pleased with the results and will try it again.

EXPERIMENT NO. 29.

Conducted by George W. Brown, Berkshire, Tioga County. In a five-acre field of potatoes about three-fourths of an acre was sprayed three times with an Auto-spray compressed-air sprayer.

Two unsprayed rows eight rods long, 33 inches apart (exactly $\frac{1}{60}$ acre), yielded 110 pounds, or at the rate of 110 bushels per acre; while two sprayed rows only a few rows away, of the same length, on the same kind of soil and same variety (Carman No. 3), yielded 200 pounds or at the rate of 200 bushels per acre. This makes the gain from spraying 90 bushels per acre. The average yield of the unsprayed portion of the field, which was all of the variety Carman No. 3, was about 100 bushels per acre. Some sprayed rows of Green Mountain in the same field yielded at the rate of 300 bushels per acre.

The unsprayed rows were not injured by bugs but they blighted badly. They were all dead before September 1, while the sprayed rows, although affected, were not entirly dead until killed by frost. There was about three weeks difference in growth.

About the same amount of rot was found on the sprayed rows as on the unsprayed. The difference in yield was mainly due to the increased size of the tubers on the sprayed rows. Price of potatoes, 40 cents.

EXPERIMENT NO. 30.

Conducted by George W. Belden, Berkshire. One-half of a two-acre field of potatoes, variety Carman No. 1, was sprayed once with a Garfield knapsack sprayer. The unsprayed half of the field was treated three times with paris green, which kept bugs well under control.

An unsprayed row 450 feet long yielded 420 pounds, or at the rate of 225 bushels 49 pounds per acre, while a sprayed row yielded 450 pounds, or at the rate of 241 bushels 57 pounds per acre, making a difference of 16 bushels 8 pounds per acre in favor of spraying.

The unsprayed portion of the field was killed by blight and the sprayed portion, also, suffered considerably. The quantity

of rotten tubers was estimated at 12½ bushels per acre and there seemed to be nearly if not quite as many on the sprayed as on the unsprayed.

Mr. Belden has sprayed potatoes for a number of years past. Sometimes he was positive it paid, but in other seasons he was in doubt.

The market price of potatoes at digging time was 40 cents per bushel.

EXPERIMENT NO. 31.

Conducted by G. G. Hitchings, South Onondaga, Onondaga County. Eight acres of potatoes were sprayed three times (July 6, 24 and August 15) with a Niagara Gas sprayer set on a two-horse cart rigged to spray two rows at a time with three Vermorel nozzles per row. The spray mixture used was made by the following formula: 5 pounds copper sulphate, about four pounds lime, 2½ pounds arsenate of lead (for bugs) and 50 gallons of water.

In one lot containing 1¾ acres, six rows of the variety Mammoth Whiton were sprayed only once (July 6), while the remainder were sprayed three times. Unfortunately, no rows were left entirely unsprayed. The six rows sprayed but once yielded 12 bushels of marketable potatoes and 2 bushels of rotten ones, while six three-sprayed rows of the same variety yielded 21 bushels of marketable potatoes *with only seven rotten tubers.* These yields are at the rate of 125 bushels 38 pounds per acre for the once-sprayed rows and 219 bushels 52 pounds per acre for the three-sprayed rows, making a difference of 94 bushels 14 pounds per acre for the two extra sprayings. The potatoes on the heavily-sprayed rows were also of better quality. Most of the crop was sold at prices ranging from 50 to 60 cents per bushel.

The three-sprayed rows outlived the once-sprayed rows by 20 days although the latter were not injured by bugs. The principal enemies fought in this experiment were late blight and flea-bettles.

In the 1¾-acre lot above mentioned, only one-fourth of the area was planted with Mammoth Whiton and the remainder with Rural New Yorker No. 2. The latter variety yielded much the better, bringing the average yield for the 1¾ acres up to 253 bushels per acre.

Mr. Hitchings is of the opinion that many farmers do not spray as thoroughly as they should to get good results. He advocates the use of about 80 pounds pressure in order to get a fine mist-like spray.

EXPERIMENT NO. 32.

Conducted by P. S. Doolittle, Cassville, Oneida County. He sprayed 7½ acres of potatoes, mostly of the variety Carman No. 3, four times with a one-horse, four-row, Aspinwall sprayer having one Vermorel nozzle per row. Four rows were left unsprayed for a check. The total cost of spraying, including an allowance of $2 for wear on sprayer, was $19.50. There were so few bugs that no poison was used on either the sprayed or unsprayed rows.

The sprayed rows still retained about half their foliage when frost came, but the unsprayed rows died about four weeks before frost.

On one of the unsprayed rows 72 hills three feet apart yielded 2 bushels, or at the rate of 134 bushels 26 pounds per acre, while the same number of hills on the adjacent sprayed row yielded 3 bushels, or at the rate of 201 bushels 40 pounds per acre, making a gain of 67 bushels 14 pounds per acre in favor of spraying. There was much more rot on the unsprayed row than on the sprayed, the loss on the latter being only about one bushel per acre. On another variety, Stump the World, in the same field and sprayed in the same manner the loss from rot was about 50 bushels per acre. The vines of this variety grew so very large that Mr. Doolittle found it impossible in the last two sprayings to cover all of the foliage with only one nozzle per row. Moreover, the large growth of vines made conditions exceptionally favorable to blight and rot.

Mr. Doolittle believes that spraying increased his crop by 50 per ct. His average yield was 200 bushels per acre, while neighboring unsprayed fields averaged 100 to 125 bushels per acre.

Market price of potatoes at digging time, 50 to 60 cents.

EXPERIMENT NO. 33.

This experiment was made by J. D. Clegg, Jefferson, Schoharie county. About one-half acre of potatoes, variety Green Mountain, was sprayed three times with a small hand sprayer, the total

expense for labor and material being $2.60. Two rows 90 feet long were left unsprayed.

The two unsprayed rows yielded 240¼ pounds, or at the rate of 323 bushels per acre; while the two adjacent sprayed rows (one on either side) yielded 260½ pounds, or at the rate of 350 bushels 13 pounds per acre, making the gain from spraying 27 bushels 13 pounds per acre. It is believed that the difference in yield was entirely due to the spraying. There was no damage done by bugs.

Although the tops did not blight much there were some rotten tubers, the quantity being somewhat greater on the unsprayed than on the sprayed rows.

The market price of potatoes at digging time was 35 cents per bushel.

EXPERIMENT NO. 34.

Conducted by Jay T. Buchanan, Akin, Montgomery County, who sprayed five acres of potatoes for himself and five acres for his brother. Five sprayings were made with an Aspinwall four-row sprayer having two nozzles per row and applying about 50 gallons of bordeaux per acre at each spraying.

The items of expense for spraying five acres of potatoes five times are as follows:[44]

27 barrels bordeaux mixture at 44½c.	$12 01
6 days' labor for man and horse at $2.25	13 50
Wear on sprayer	3 00
Total	$28 51

In one of Mr. Buchanan's own fields one row (Row O) 432 feet long was left unsprayed. The adjacent row on the east (Row C) was sprayed five times with 50 gallons of bordeaux per acre each time; the second row on the east (Row D), the same; the adjacent row on the west (Row B) received two 50-gallon sprayings followed by two double or 100-gallon sprayings; while the second row on the west (Row A) received two 50-gallon sprayings followed by three double or 100-gallon spray-

[44] The expense here given is only for Mr. Buchanan's five acres. No record was kept of the expense of spraying on his brother's field.

ings. All were of the same variety, namely, Mills Prize. The accompanying table shows the yield:

TABLE XII.—SHOWING YIELDS IN EXPERIMENT NO. 34.

ROW.	How sprayed.	Yield per row.	Yield per acre.		Gain per acre due to spraying.	
		Lbs.	*Bu.*	*lbs.*	*Bu.*	*lbs.*
A............	2 (50 gals.) + 3 (100 gals.)...	545	305	17	60	46
B............	2 (50 gals.) + 2 (100 gals.)...	525½	294	22	49	51
O............	Not sprayed.................	436½	244	31	—	—
C............	5 (50 gals.)..................	476	266	28	21	57
D............	5 (50 gals.)..................	492	275	36	31	5

There was noticeably more rot on the unsprayed row than on the sprayed but not much in any case.

The results in this experiment again emphasize the importance of thorough spraying. It should also be noted that Row D outyielded Row C sprayed in the same way. This is another example of the oft-observed fact that a sprayed row adjacent to an unsprayed row does not yield as well as the second sprayed row. Mr. Buchanan's potatoes were planted June 8; consequently, they were still growing when frost came, September 21. Had it not been for the frost the gain due to spraying would have been considerably larger. We examined this experiment August 12 at which time the plants were very large and there were already traces of late blight on unsprayed rows, but it appears that the disease did not work as rapidly here as in some other localities. The attack of blight was only moderately severe.

Another season Mr. Buchanan will plant early and spray thoroughly. The market price of potatoes at digging time was 50 to 55 cents.

EXPERIMENT NO. 35.

Conducted by John Jeannin, Jr., West Sand Lake, Rensselaer County. One acre of Green Mountain potatoes, in two plats, were sprayed three times with a five-gallon compressed-air sprayer like the one used in the Sliters Experiment (see page 128; also Plate XVI, fig. 1). In each plat two rows 100 feet long were left unsprayed. The total expense of spraying was $4.68, the items being as follows:

97 gallons bordeaux mixture..........................	$0 68
8 pounds arsenate of lead at 20c....................	1 60
16 hours labor at 15c..................................	2 40
Total	$4 68

In this experiment there appears to have been no late blight whatever, no rot, and but little, if any, early blight. The chief enemy was the flea-beetle which did considerable damage to the unsprayed rows. When we saw the experiment field on August 12, the plants were somewhat affected with tipburn. At that time the sprayed rows were in but slightly better condition than the unsprayed, and up to the close of the season there was no marked contrast. The yields were as follows:

Two sprayed rows (north plat), 161 pounds.[45]

Two sprayed rows (south plat), 188 pounds.

Average yield per sprayed row, 87¼ pounds or 211 bushels 9 pounds per acre.

Two unsprayed rows (north plat), 127 pounds.

Two unsprayed rows (south plat), 153 pounds.

Average yield per unsprayed row, 70 pounds or 169 bushels 24 pounds per acre.

Average gain due to spraying, 41 *bushels* 45 *pounds per acre.*

Market price of potatoes at digging time, 50 cents per bushel.

EXPERIMENT NO. 36.

Conducted by J. H. Beadle, Washington County. Three rows across a ten-acre field were sprayed three times with an Auto-Spray compressed-air sprayer. (Plate XVI, fig. 2.) The potatoes were of the variety World's Fair.

There was not much difference in appearance between the sprayed and unsprayed rows until about September 12 when the unsprayed rows suddenly blighted and died while the sprayed rows continued green until killed by frost September 22.

Owing to the pressure of farm work Mr. Beadle was unable to compare the yield of sprayed and unsprayed rows as carefully as he wished. However, he did weigh the tubers from 25 sprayed hills three feet apart, and also those from 25 unsprayed hills in an adjacent row, with the following results:

Twenty-five sprayed hills, 92 pounds or at the rate of 296 bushels 51 pounds per acre.

Twenty-five unsprayed hills, 77 pounds or at the rate of 248 bushels 27 pounds per acre.

Gain due to spraying, 48 bushels 24 pounds per acre.

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[45] On both plats the sprayed rows measured were next to the unsprayed rows.

In the 25 unsprayed hills there were 3 pounds of rotten tubers, but none whatever in the sprayed hills. The unsprayed rows were not injured by bugs. Market price of potatoes at digging time, 90 cents per barrel or 30 cents per bushel.

EXPERIMENT NO. 37.

Conducted by D. Lewis Downs, Baiting Hollow, Long Island. Thirty-five acres of potatoes, variety Green Mountain, were sprayed four times, eight rows six times and 25 rows 49 rods long, 34 inches apart, left unsprayed except that they were treated twice with poison for bugs.

The spraying was done with a one-horse Watson sprayer covering four rows at a time with one nozzle per row. The total expense of spraying, including all labor, chemicals, paris green and wear on sprayer was $3.80 per acre or 95 cents per acre for each spraying. Mr. Downs thinks that with experience he can reduce this somewhat.

The yields were as follows:

Eight rows sprayed six times, 105 bushels or at the rate of 249 bushels 35 pounds per acre.

Eight rows sprayed four times, 101 bushels or at the rate of 240 bushels 4 pounds per acre.

Eight rows unsprayed, 83 5-6 bushels or at the rate of 199 bushels 16 pounds per acre.

Thus the gain from four sprayings was 40¾ bushels per acre and from six sprayings 50 1-3 bushels.

As the test rows were dug the potatoes were hauled directly to the railroad station where they were weighed and sold. Accordingly, the yields given above are based on actual selling weight. The eight six-sprayed rows measured were separated from the eight unsprayed rows by only two rows, while the eight rows sprayed four times adjoined the six-sprayed rows and were about 28 feet from the unsprayed rows. There was not much rot on the sprayed rows, but the unsprayed rotted badly.

When digging was commenced potatoes sold for 40 cents per bushel, but by the time it was finished the price had risen to 60 cents.

EXPERIMENT NO. 38.

Conducted by F. N. Moseley, Riverhead, Long Island. In a field of eleven acres of potatoes about nine acres were sprayed

six times with a one-horse, Watson sprayer covering four rows at a time with one nozzle per row. The remaining two acres were not sprayed.

We examined this experiment at the time of the fifth spraying, August 8. On the unsprayed portion of the field, flea-beetles, early blight and late blight were all abundant and it was plain that they would soon ruin the plants. At the same time the sprayed portion of the field was in fairly good condition although infested to a considerable extent by all three enemies above mentioned. The plants were so large that they covered the ground completely, making it impossible to do a thorough job of spraying with but one nozzle per row.

One of the writers was present when the test rows were dug and assisted with the weighing. A sprayed row 37½ rods long yielded 832 pounds of marketable tubers or at the rate of 325½ bushels per acre; while an unsprayed row 38½ rods long yielded 526½ pounds or at the rate of 200½ bushels per acre, making a difference of 125 bushels per acre in favor of spraying. However, it may be that all of this difference was not due to spraying. Although the sprayed and unsprayed rows were on the same kind of soil and seemed to have an equal chance in all respects save the matter of spraying, they can not be closely compared because they were about 80 feet apart.

In another portion of the same field a row sprayed six times outyielded a row sprayed three times by 26 bushels 21 pounds per acre.

The market price of potatoes at digging time was 50 cents per bushel.

EXPERIMENT NO. 39.

Conducted by H. M. Reeve on the farm of G. O. Hallock, Mattituck, Long Island. Each time after spraying his own field Mr. Reeve went out and back with the sprayer across Mr. Hallock's potato field covering 14 rows. These rows were about 34 rods long, 26 of them being required to make an acre. They were sprayed four times, commencing July 12 and repeating once a week. The sprayer used was a one-horse, Schanck sprayer like the one shown in Plate XIII, fig. 1. The total cost of spraying was $1.60 per acre.

At digging time four rows in the middle of the sprayed strip were weighed as were also four unsprayed rows on each side. The yields were as follows:

Four sprayed rows, 2,546 pounds or at the rate of 277 bushels 29 pounds per acre.

Four unsprayed rows on the south, 2,010 pounds.

Four unsprayed rows on the north, 1,830 pounds.

Average yield of the unsprayed rows, 208 bushels per acre.

Gain due to spraying, 69½ bushels of marketable tubers per acre.

Most of the gain was due to the prevention of rot. On the unsprayed rows more than one-fourth of all the tubers were rotten, while on the sprayed rows there were but few rotten tubers.

This experiment differs from most of the others in that only a narrow strip was sprayed while the remainder of the field, about five acres, was left unsprayed.

The market price of potatoes at digging time was 50 cents per bushel.

EXPERIMENT NO. 40.

Conducted by W. A. Fleet, Cutchogue, Long Island. One field of about nine acres and another of a little less than one acre were sprayed four times, commencing July 19 and repeating at intervals of eight days. The sprayer used was a New Hudson which sprays four rows at a time with two nozzles per row. The expense of spraying was about 64 cents per acre for each application.

In the nine-acre field there were no unsprayed rows, but in the smaller field, which was of the variety Rural New Yorker No. 2, one row 27 rods long was left unsprayed. We saw this experiment on August 9 at which time both the sprayed and unsprayed rows were quite badly attacked by late blight, but the unsprayed row was much the worse. Mr. Fleet informs us that the unsprayed row died two weeks earlier than the sprayed.

The unsprayed row yielded 355 pounds or at the rate of 192 bushels 49 pounds per acre, while an adjacent sprayed row yielded 470 pounds or at the rate of 255 bushels 17 pounds per acre, making the gain due to spraying 62 bushels 28 pounds per acre. The greater yield on the sprayed rows was mainly due to the increased

size of the tubers. There was no rot worth mentioning on either the sprayed or unsprayed plants.

The market price of potatoes at digging time was 50 cents per bushel.

EXPERIMENT NO. 41.

Conducted by Charles B. Foster, Water Mill, Long Island. Ten acres of potatoes, Carman No. 1, were sprayed twelve times with a Schanck sprayer. About one-half acre was left unsprayed. The items of expense were as follows:

362 pounds copper sulphate, at 5¾c	$20 82
400 pounds copper sulphate, at 7c	28 00
3 barrels lime, at $1.85	5 55
108 hours labor for man, at 17½c	18 90
54 hours labor for horse, at 10c	5 40
52 pounds paris green, at 15c	7 80
Wear on sprayer	4 00
Total	$90 47

An unsprayed row 26 rods long, 34 inches wide, yielded 383 pounds or at the rate of 228 bushels 45 pounds per acre, while a nearby sprayed row yielded 518 pounds or 309 bushels 23 pounds per acre, making a difference of 80 bushels 38 pounds of marketable tubers per acre in favor of spraying.

Contrary to the usual experience there was more rot on the sprayed than on the unsprayed rows. Mr. Foster estimates the loss from rot at 40 bushels per acre on the sprayed areas and 15 bushels per acre on the unsprayed. The explanation of this seems to be that the weather conditions most favorable to rot came after the unsprayed plants were dead and dry and the blight spores mostly dead. The sprayed plants, on the contrary, were still green and covered with live spores of late blight which, falling upon the ground, caused the tubers to rot. In this part of Long Island late blight was particularly severe. In spite of thorough spraying the disease made steady progress and caused considerable damage. When we saw this experiment on August 10 the unsprayed rows were entirely dead while the sprayed rows retained about three-fourths of their foliage. Mr. Foster

says that the sprayed rows lived 19 days longer than the unsprayed.

The market price of potatoes at digging time was 40 cents, but Mr. Foster realized an average price of 53 cents per bushel on his entire crop.

SUMMARY OF VOLUNTEER EXPERIMENTS IN 1904.

The principal features of the forty-one volunteer experiments are shown in the following table:

TABLE XIII.—SHOWING RESULTS OF VOLUNTEER EXPERIMENTS.

Experiment.	NAME.	Location.	Area Sprayed.	Times Sprayed.	Yield per Acre.[46] Sprayed.	Yield per Acre.[46] Un-sprayed.	Gain per acre due to spraying.		Cost per acre each spraying.	Price of potatoes.
			A.		*Bu.*	*Bu.*	*Bu.*	*Lbs.*		
1	Kirkland....	Dewittville.....	2¾	5	212	184½	27	30	....	$0 50
2	Ransom.....	Ransomville...	20	4	167	131	36	18	$0 33	50
3	Grinnell.....	Albion.........	2	4	146	63	83	1	1 50	60
4	Driggs.......	Elba..........	10	4	132	110	22	0	....	40
5	French......	Gainesville.....	11½	5	143½	89½	53	45	63⅓	45
6	Dusen.......	Gainesville.....	15	3	210½	134½	75	46	....	45
7	Taylor.......	Hardys........	5	4	166	114	52	0	....	40
8	Wilson......	Castile.........	8	4	165½	139½	26	13	....	45
9	Beaumont...	Castile.........	11	5	158	134	24	12	....	45
10	Cridler.......	Hornellsville...	9¼	3	279½	256	23	18	51	40
11	Schenck.....	Jasper.........	2¼	4	162	126	36	0	....	35
12	Hollenbeck..	Jasper.........	2	1	228	195½	32	36	....	35
13	Zimmerman..	Adams Basin...	5	8	241½	198½	43	8	90	50
14	Babcock.....	Spencerport....	18	5	164	133½	30	29	47⅓	50
15	Dobson......	Charlotte......	4½	3	179	122	57	0	....	65
16	Norris.......	West Rush.....	4½	8	271	74½	196	24	65⅓	40
17	Martin......	West Rush.....	17	....	287	225	62	0	....	40
18	Dell.........	East Rush.....	12	4	172	137	35	39	45	65
19	Schoen......	Pittsford.......	15	4	232½	142	90	13	....	40
20	Battams.....	Fishers........	24	2	256	233	23	20	1 03	45
21	Green.......	Victor.........	14	8	200	130	70	0	....	40
22	Van Voorhis.	Hopewell......	15	5	205	137	68	25	....	40
23	Welch.......	Phelps.........	5	2	316½	305½	10	50	73	40
24	Salisbury....	Phelps.........	7	4	144½	104	40	43	76¾	40
25	Salisbury....	Phelps.........	15	5	192½	126	66	37	80	40
26	Salisbury....	Phelps.........	10	4	206½	110½	96	25	1 00	40
27	Hadlow......	Geneva........	¼	6	304	148	156	12	....	50
28	Bradley......	Interlaken.....	5¼	4	207	144	62	48	1 85	35
29	Brown.......	Berkshire......	¾	3	200	110	90	0	....	40
30	Belden......	Berkshire......	1	1	242	226	16	8	....	40
31	Hitchings....	S. Onondaga...	8	3	220	125½	94	14	1 41	50
32	Doolittle.....	Cassville.......	7½	4	201½	134½	67	14	65	50
33	Clegg........	Jefferson.......	½	[illegible]	350	323	27	13	1 73⅓	35
34	Buchanan....	Akin...........	10	6	275½	244½	31	5	1 14	50
35	Jeannin......	W. Sand Lake..	1	5	211	169½	41	45	1 56	50
36	Beadle.......	Cambridge.....	¼	3	297	248½	48	24	....	30
37	Downs.......	Baiting Hollow.	35	4	240	199	40	48	95	50
38	Moseley.....	Riverhead.....	9	6	325½	200½	125	0	....	50
39	Reeve.......	Mattituck......	½	4	277½	208	69	29	40	50
40	Fleet........	Cutchogue.....	10	4	255	193	62	28	64	50
41	Foster.......	Water Mill.....	10	12	309½	229	80	38	75⅓	40

Total area sprayed in 41 experiments, 363¾ acres.

Average increase in yield per acre, 58 bushels 28½ pounds.

[46] Computed to nearest half bushel.

Average total cost[47] of spraying per acre (23 experiments), $3.91.

Average cost per acre for each spraying (23 experiments), 90 2-3 cents.

Average market price of potatoes at digging time, 43½ cents per bushel.

Average net profit per acre (23 experiments), $22.01.

AN EXPERIMENT TO DETERMINE THE RELATIVE EFFICIENCY OF SOLUBLE BORDEAUX, SODA BORDEAUX AND LIME BORDEAUX FOR THE PREVENTION OF POTATO BLIGHT, *PHYTOPHTHORA INFESTANS*.

INTRODUCTION.

Soluble bordeaux.—At the request of Director W. A. Henry of the Wisconsin Experiment Station we made a test of the "soluble bordeaux" devised by Dr. S. M. Babcock of the same Station. Concerning the preparation and use of soluble bordeaux Dr Babcock gave us the following instructions:

Stock Solutions.

1. Copper sulphate solution:

Dissolve one pound of copper sulphate in two gallons of cold water. Will keep indefinitely.

2. Solution of sucrate of lime:

Slake ten pounds of fresh lime in 30 pounds of water, strain the milk of lime through a wire strainer and add a solution of 25 pounds of granulated sugar in 50 pounds of water. Stir thoroughly at frequent intervals, and after two or three hours decant or siphon the clear liquid from the undissolved lime. The lime and sugar solution can be conveniently mixed in a revolving barrel churn.

The quantities named are sufficient for about eight gallons of standard solution of sucrate of lime.

The solution will keep indefinitely if placed in well stoppered bottles, but if open to the air will gradually absorb carbonic acid gas and the lime will separate.

After siphoning off the clear solution the residue still contains some sugar which may be recovered by adding considerable water and allowing the residue to settle a second time. The clear solution obtained may be used in place of an equal quantity of water in the preparation of the next lot.

Soluble Bordeaux.

Take equal parts of solution 1 and 2 and add three parts of water. Agitate until the copper hydrate which is at first precipitated is entirely dissolved.

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[47] In every one of the 23 experiments which enter into this average the cost given includes both labor and materials and in most cases also poison for bugs and an allowance for the wear of machinery.

Upon standing a slight deposit of gypsum is formed leaving a deep blue solution of hydrate of copper. If desired the spray may be applied immediately after preparation as the small amount of finely divided gypsum will not interfere. Prepared in this manner the solution contains about the same amount of copper hydrate as the ordinary bordeaux mixture. It may be diluted indefinitely with water without a precipitate forming. The solution should be kept in well stoppered bottles and is best if used within 48 hours after preparation.

In case complete solution of the copper hydrate is not obtained, add a little more of solution No. 2 of sucrate of lime.

It is believed, on account of the soluble condition of the copper hydrate in this preparation, that its efficiency as a fungicide will be much greater than in the ordinary bordeaux mixture and consequently that it may be diluted at least ten and possibly fifty times and still protect plants from the ordinary fungus diseases. In addition to this advantage the absence of solid particles permits the use of a much finer spray than is now employed and it is evident that with a fine spray much more surface can be covered with the same amount of material. In these two ways it is hoped that the expense for the materials used in spraying may be greatly reduced.

Soda bordeaux.—Considerable interest in soda bordeaux for potatoes has been aroused recently by Prof. S. Fraser[48] who calls attention to the fact that some experiments made in Ireland tend to show that soda bordeaux is superior to the regular lime bordeaux as a preventive of potato blight.[49] The experiments mentioned extended over three years, included nine varieties, and each year soda bordeaux gave better results than lime bordeaux. The average yield per acre for the three years was as follows: Lime bordeaux, 370 bushels; soda bordeaux, 391.7 bushels; unsprayed, 303.9 bushels. Thus the lime bordeaux gave an average gain of 66 bushels and the soda bordeaux, 88 bushels per acre. The lime bordeaux was made by the 8-4-40 formula or the 1-to-5 formula, which is stronger than it is used in this country. The soda bordeaux, also, was made by the 1-to-5 formula with 10 pounds of washing soda (sal soda) substituted for the lime.

As these results are not in harmony with accepted belief on the subject the writers thought it advisable to make farther experiments comparing soda bordeaux with lime bordeaux and with Dr. Babcock's soluble bordeaux.

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[48] Fraser, S. Treatment for Potato Blight. *Country Gentleman,* 69:510. June 2, 1904.

Ibid. A New Treatment for Potato Blight. *American Agriculturist,* 73: 668. June 18, 1904.

Ibid. The Potato, p. 131. Orange Judd Co., New York. 1905.

[49] Prevention of Potato Blight. Department of Agriculture and Technical Instruction for Ireland. Leaflet No. 14.

The experiment.—The experiment included sixty rows of potatoes, 100 feet long and three feet apart. The hills were 18 inches apart in the row, the planting being done by hand. The land grew corn in 1903. No manure or fertilizer was applied for the potato crop. These potatoes were not planted for experimental purposes but merely to fill out the ends of the rows used in some other spraying experiments. Accordingly they were not planted with the care usually taken in experimental-work. They were planted quite late, about June 10. The variety was Rural New Yorker No. 2.

When the plants were 6 to 9 inches high they were attacked by hordes of Colorado potato beetles and treatment being delayed considerable injury was done. Some of the plants were almost completely defoliated. On July 26, paris green in limewater (1 pound to 50 gallons) was applied over the entire 60 rows. Rain coming the same day the treatment was not as effective as desired, hence another application of paris green was made on July 29. After this there was no more trouble from beetles until August 12, when they were again sufficiently numerous on the check rows to require another application of paris green. This time only the check rows were treated.

PLAN OF THE EXPERIMENT.

The sixty rows were divided into four series of 15 rows each as follows:

Series I. Rows 1, 5, 9, 13, 17, 21, 25, 29, 33, 37, 41, 45, 49, 53, 57 were left untreated for a check.

Series II. Rows 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58 were treated with soluble bordeaux.

Series III. Rows 3, 7, 11, 15, 19, 23, 27, 31, 35, 39, 43, 47, 51, 55, 59 were treated with soda bordeaux.

Series IV. Rows 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48, 52, 56, 60 were treated with the regular lime bordeaux.

Series II, III and IV were very thoroughly sprayed, by means of a knapsack sprayer, four times, August 2, 8, 19 and September 1. In the last two sprayings 16 gallons were required to spray the fifteen rows of each series.

PREPARATION OF SPRAY MIXTURES.

Soluble bordeaux.—(1) Solution of copper suplhate prepared by dissolving one-half pound copper sulphate in one gallon of water.

(2) Solution of sucrate of lime furnished by the Wisconsin Experiment Station.

One quart of (1) was mixed with one quart of (2) and three quarts of water. After standing 15 or 20 minutes this mixture (containing five quarts) was added to 95 quarts of water, making a total of 100 quarts, and spraying commenced at once.

Soda bordeaux.—Two pounds of copper sulphate was dissolved in two quarts of water by boiling, then diluted to 32 quarts. Two and one-half pounds washing soda was dissolved in two quarts of water by boiling. After being cooled this was poured into 32 quarts of copper sulphate solution and enough water added to make 64 quarts in all. The litmus test indicated that the mixture was very nearly neutral.

Lime bordeaux.—Two pounds of copper sulphate dissolved in 32 quarts of water. To this was added a quantity of milk of lime equal to about one and one-half times that required to satisfy the potassium ferrocyanide test. Finally, enough water was added to make 64 quarts in all. This is the regular 1-to-8 formula which we recommend for spraying potatoes.

NOTES.

The first application was made in the forenoon of August 2. In the afternoon there was rain and it is likely that the last five rows in Series II (soluble bordeaux) did not get thoroughly dry before the rain came.

Between the first and second sprayings considerable rain fell. Nevertheless, on Series III and IV the mixture applied in the first spraying was quite conspicuous at the time of making the second one. Whether the soluble bordeaux was washed off by rain was impossible to determine because it does not discolor the foliage at all. It was impossible to tell which rows had been sprayed and which not. For use on potatoes this feature of the soluble bordeaux is a decided disadvantage. The same thing was observed at the time of the third and fourth sprayings. Series III and IV showed abundant evidence of the mixture applied in the previous spraying, but on Series II there was no discoloration of the foliage, not even immediately after spraying.

At no time was there any evidence of spray injury on any of the series.

At the time of the first spraying, August 2, there were traces of blight (*Phytophthora infestans*) all over the field, but even on the unsprayed rows it made slow progress until after September 1.

On September 8 notes were made on the condition of the different series. On the check rows in the east half of the experiment field there was considerable blighted foliage, while check rows in the west half of the field were but slightly affected. Throughout the experiment the rows sprayed with soluble bordeaux were somewhat less affected than the check rows adjacent, but much more affected than the rows sprayed with soda bordeaux or those sprayed with lime bordeaux, on which the foliage was nearly perfect. There seemed to be no difference between Series III and IV.

On September 21 there was still but little blight in the west half of the experiment, while in the east half the check rows were mostly dead. The soluble bordeaux rows were appreciably better than the check rows but much inferior to the two bordeaux series.

On September 29 the check rows were practically dead throughout the experiment. Soluble bordeaux rows were but little better, being all dead over the east half of the experiment and with but little green foliage in the west half. The two bordeaux series were about equal, with probably three-fourths of their foliage in good order; but from this date on they deteriorated rapidly and were finally killed by frost October 6.

YIELDS.

The potatoes were dug by hand October 24 and 25. The product of each series was thrown onto a large table and carefully sorted, by the writers, into marketable, rotten and small. The yield by series is shown in the accompanying table.

TABLE XIV.—YIELD BY SERIES IN EXPERIMENT WITH DIFFERENT KINDS OF BORDEAUX.

SERIES.	YIELD PER SERIES.			YIELD PER ACRE.					
	Marketable.	Rotten.	Small.	Marketable.		Rotten.		Small.	
	Lbs.	*Lbs.*	*Lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
I Check	667	36	84	107	29	5	48	13	32
II Soluble bordeaux	735	88	87	118	27	14	11	14	1
III Soda bordeaux	987½	10	62	159	9	1	37	10	0
IV Lime bordeaux	1091	26½	69	175	50	4	26	10	48

From the above table it will be seen that the gains due to spraying were as follows:

Soluble bordeaux, 10 bu. 58 lbs marketable tubers per acre.
Soda bordeaux, 51 bu. 40 lbs. marketable tubers per acre.
Lime bordeaux, 68 bu. 21 lbs. marketable tubers per acre.

COMMENTS ON RESULTS.

It is possible that the soluble bordeaux was at a slight disadvantage in the first spraying for the reason that five of the rows were but partially dry when rain came. However, we believe it improbable that this had much influence on the results because a second spraying was made only six days later, August 8, and subsequent events indicate that but little infection occurred during the interval. Blight did not get well under way until after September 1.

With the exception above noted, the test seems to have been a fair one. While there were doubtless slight inequalities in planting, it is probable that they were pretty evenly divided among the four series.

It will be seen that there was more than twice the weight of rotten tubers on the soluble bordeaux rows that there was on the check. The reason for this is not clear. The rot was practically all due to *Phytophthora,* that is, a direct consequence of the blight affecting the tops. Most of the affected tubers were in the early stages of the rot and it is unlikely that the smaller amount of rot on the check can be attributed to the more complete decay of the tubers on those rows. Probably the soil and weather conditions were more favorable to rot late in the season after most of the blight spores on the check rows had dried up. On the sprayed plants the blight spores lived longer because the foliage continued green longer.

The increased yield on the sprayed series was chiefly due to the prevention of late blight, *Phytophthora infestans.* There was no early blight and no injury by flea-beetles.

In this experiment blight was not as virulent as in other spraying experiments in the same field. This was largely due to the fact that the plants were much smaller, owing to lack of fertilizer. Probably, also, the three heavy applications of paris green to the check rows protected them considerably against blight.

In another experiment made the past season four similar applications of paris green increased the yield about 46 bushels per acre through partial prevention of blight.[50]

CONCLUSIONS.

Soluble bordeaux, as used in this experiment, has slight value as a preventive of potato blight (*Phytophthora*), but is far inferior to soda bordeaux and the regular lime bordeaux of the 1-to-8 formula. Probably it is useless to experiment with dilutions greater than that used in this experiment.

Soda bordeaux proved inferior to lime bordeaux. It is not to be recommended, at least until further tests[51] have been made. Its only advantage is that it does not clog the spray nozzles so readily. It has the disadvantage that arsenite of soda can not be used with it safely except by the addition of lime.

POTATO TROUBLES IN NEW YORK IN 1904.

In New York the season of 1904 was cool, with an abundance of rain, making conditions generally favorable for potatoes, except in the matter of blight. Owing to the protracted wet weather in the spring, planting was much delayed in some localities. Many fields were planted from June 5 to 15. A large propor-

[50] Details of this experiment will be given in a subsequent bulletin.

[51] The soluble bordeaux has been tested also by Director Woods of the Maine Station with similar results (Me. Exp. Sta. Bul. 112:8–12). His conclusions are as follows: "The soluble bordeaux of equal strength to regular bordeaux mixture cost much more, both in materials and labor, than regular bordeaux mixture. The yields were smaller and the quality inferior from the plots sprayed with soluble bordeaux. For both of these reasons its use is not recommended."

It should be stated that only carefully conducted experiments are of any value in solving this problem. Such experiments as farmers make are not sufficiently accurate. The difference in efficiency between soda bordeaux and lime bordeaux is certainly not great—not more than a few bushels per acre—and there are several other factors which, unless eliminated from the experiment, would make the results unreliable. Only two such factors need be mentioned: (1) Inequality of soil. Soil varies so much that the yields of adjacent plats treated as nearly alike as possible often vary by 25 to 50 bushels per acre. Hence, wide plats are objectionable. The plats should be long and narrow (preferably consisting of a single row) and repeated several times as in the above experiment (Page 179) and in the Station ten-year experiments (Page 91.) (2) Thoroughness of spraying. Great care must be taken that the soda bordeaux and lime bordeaux plats are sprayed with equal thoroughness. Even a slight variation in the thoroughness of spraying may materially affect the yield.

In the report of the Irish experiments cited by Prof. Fraser few details are given, making it impossible to determine whether the experiments were properly conducted.

tion of these late-planted fields were killed by frost on September 22, before the plants had completed their growth. This was especially true of sprayed fields which were protected from blight. Had it not been for frost, several of the experiments reported in this bulletin would have shown considerably larger gains due to spraying. In our opinion, late potatoes in this State should be planted before May 25, in order that they may mature before frost.

Late blight, *Phytophthora infestans,* was destructive over the greater part of the State. In western and central New York and on Long Island it caused enormous loss. It appeared in the latter part of July and during August became very virulent. In the majority of the fields the blight was followed by more or less rot. Through the northern part of the State late blight was not destructive until nearly the close of the season, but it was followed by a violent attack of rot. For example, in Franklin County losses of 25 to 50 per ct. of the crop were not uncommon.

The localities suffering least from blight and rot were in the eastern part of the State, in Columbia, Rensselaer and Washington Counties and along Lake Champlain.

Early blight was very unimportant. It caused some damage on Long Island and also in a few fields in other parts of the State, but it was not common. About the same may be said of flea-beetles. On Long Island they were exceedingly numerous and destructive, but elsewhere in the State they were not troublesome except in a few localities. Colorado potato beetles or "bugs" as they are called were also less troublesome than usual. In many cases there were so few that it was unnecessary to use poison for them.

We estimate that the loss from potato blight and rot in 1904 was at least 60 bushels per acre on the average. In 14 farmers' business experiments spraying increased the yield 62¼ bushels per acre and the average gain from spraying in 41 other experiments by farmers was 58½ bushels per acre. As these experiments were well distributed over the State they should represent the average conditions fairly well, Besides it should be taken into consideration that in many of these experiments the spraying was not thoroughly done so that the blight was only partially

controlled. At the Experiment Station the loss from blight was 233 bushels per acre as shown by the results of spraying in the ten-year experiment. Had the spraying in the farmers' experiments been as thorough as that done at the Station it is probable that the gain from spraying would have been doubled in many cases. Few farmers realize how great is the loss caused by potato blight.

PROGRESS OF POTATO SPRAYING.

It is gratifying to note that the practice of spraying potatoes for blight is very evidently on the increase in New York. During the past season much more potato spraying was done than ever before and the indications are that in 1905 there will be still greater activity along this line. Western New York (Monroe and Ontario Counties) and Eastern Long Island are taking the lead. Considerable spraying has been done, also, in Wyoming and Steuben Counties.

However, taking the State as a whole, a very small part of the crop in 1904 was sprayed. In the northern part of the State (Franklin and Clinton Counties) potato spraying is practically untried. At Chateaugay, one of the largest potato-shipping points in the State, no spraying of any importance has ever been done. Scattered all over the State are many other localities in which little or no attention has been given to spraying. Here and there are found potato growers who spray regularly and are enthusiastic over the results. Some others have experimented with it more or less and are yet in doubt as to whether it pays. But it is probable that in the majority of New York potato fields spraying has not even been tried.

The prospect for 1905 is encouraging. There seems to be a widespread interest in the subject. Many farmers who have never before sprayed are planning to do so the coming season. On Long Island, the Riverhead Farmers' Club has ordered five tons of blue vitriol to be used for spraying potatoes. No doubt this unusual interest in potato spraying is chiefly due to the heavy losses caused by blight and rot during the past three years. Should the season of 1905 be a dry one so that blight is not severe and the returns for spraying are small it is likely that interest will again lag and spraying be abandoned in 1906. We

would warn farmers against this. Unprofitable seasons are to be expected now and then; but the results of our experiments already leave little doubt that spraying will be profitable, on the average. No one can foresee whether blight will be destructive. The only safe method is to spray regularly every season.

Another indication of progress is seen in the quality and variety of potato spraying machinery now on the market. Until recently, one objection to the spraying of potatoes was the lack of suitable machinery. This objection is no longer valid. There is now a considerable variety of good, serviceable sprayers suited to fields of all sizes and for sale at reasonable prices. As the demand for them increases these sprayers will be still further perfected.

MAKING EXPERIMENTS IN 1905.

It is the intention to continue the potato spraying experiments seven years longer. In 1905 the regular ten-year experiments at Geneva and Riverhead will be conducted again as usual; also, about fifteen farmers' business experiments in different parts of the State. In addition, the Station hopes to secure reports of a large number of volunteer experiments—the more the better. An effort will be made to obtain for publication in the 1905 bulletin an account of at least one volunteer experiment from each county in the State. Some counties should furnish several experiments.

Potato growers in all parts of the State are earnestly requested to make spraying experiments in 1905 and report the results to the Station. Whatever the outcome of the experiments, whether for or against spraying, we wish the reports, provided, of course, the experiments have been properly conducted. Some rows should be left unsprayed for comparison, and they should be under practicaly the same conditions as the sprayed rows. They must be of the same variety, on the same kind of soil, treated with the same kind and quantity of fertilizer and given the same cultivation. *And the unsprayed rows must be protected from bugs.* One of the commonest faults of farmers' spraying experiments is that bugs are permitted to injure the unsprayed rows. Finally, the test rows must be measured with a tape, not paced; and the crop on them must be weighed or measured, not estimated.

It is desirable, but not necessary, that an account be kept of all expense of the spraying, including all labor, chemicals, poison for bugs and an allowance for wear of sprayer.

The sprayed and unsprayed rows to be measured should not be far apart. Probably the fairest test that can be made on a small scale is to have three unsprayed rows, then measure the crop on the middle one and also on the second sprayed row on either side. By this method two rows are left between the unsprayed row and the sprayed rows measured. This is desirable for the reason that an unsprayed row next to a sprayed row is sure to receive some benefit from spray falling upon it accidentally; and a sprayed row next to an unsprayed one does not have a fair chance, because it is less thoroughly sprayed than the other rows in the field and is also more exposed to blight.[53]

Those having four-row sprayers may prefer to leave four unsprayed rows, in order that they may use their sprayer in applying poison for bugs. In such a case we would advise measuring the crop on the middle two unsprayed rows and on the second sprayed row on either side.

The greater the length of the sprayed and unsprayed rows measured the better. They should be at least 25 rods long. Yields per acre based upon the weight of a few hills are undesirable.

MISCELLANEOUS INFORMATION ON POTATO BLIGHT AND SPRAYING.[54]

CONCERNING THE NUMBER OF SPRAYINGS.

"There is great diversity of opinion as to the number of sprayings which is most profitable. Some hold that two or three sprayings are sufficient. Others would spray frequently throughout the whole season.

" Conditions vary so much that no invariable rule can be made. The farmer must rely chiefly on his own judgment. Probably the rule which most nearly fits all cases, and the one to be fol-

[53] For an example of this see Table X showing yields in the West Henrietta experiment, p. 112.

[54] The matter included under this head is copied from Farmers' Institute Bulletin No. 2. Syllabus of Illustrated Lecture on Potato Diseases and Their Treatment. By F. C. Stewart and H. J. Eustace. Published by U. S. Dept. of Agr. Office of Experiment Stations, 1904.

lowed when in doubt, is the following: Commence spraying when the plants are 6 to 8 inches high and repeat the treatment regularly at intervals of ten to fourteen days as long as the plants live.

"Usually 'bugs' must be treated when the plants are a few inches high. Often flea-beetles are prevalent at the same time. By using bordeaux and poison together both these insects may be more effectively fought than by using poison alone. In another two weeks the second brood of bugs has appeared. A second spraying must be made for these. In two weeks more the plants are in bloom and quite large. They must now be sprayed for blight, and it is not easy to reach the lower leaves. Unless the two early sprayings have been made, it is difficult to protect the lower leaves and they fall a prey to both early and late blight. Where the vines grow large this is an important matter.

"Another advantage in commencing early is that the plants are always protected against an outbreak of late blight. As a rule it is unsafe to postpone spraying until the appearance of blight. Usually the blight becomes thoroughly established in a field before it is observed. In any case it is necessary to act very promptly, and there are likely to be unforseen hindrances, such as lack of materials or the sprayer being out of order. Then, too, it often happens that the outbreak of blight occurs during a period of wet weather when it is almost impossible to get into the field to spray. The only sure way to avoid such difficulty is to commence early and spray regularly at intervals of 10 to 14 days, as above directed. *One of the chief causes of failure is beginning too late.*

"The frequency of the spraying should depend somewhat upon the thoroughness with which the work is done. In giving the above directions for spraying it is assumed that the quantity of bordeaux applied at each spraying is at least 40 gallons per acre. If using a sprayer which applies but 25 gallons per acre, once in two weeks is not often enough. In such cases an application should be made every week. When the vines are large and the weather favorable to late blight at least 100 gallons per acre are required to do good work. The general tendency of farmers is

to make too light applications. *Many fail because they are too saving of time and material.*"

THE KIND OF SPRAYER TO USE.[55]

"The kind of sprayer to use depends chiefly upon the area to be sprayed. For gardens and fields of one acre or less, compressed-air sprayers holding three to five gallons and costing from three to eight dollars answer very well. There are also bucket pumps which may be had for the same price and which are quite satisfactory. Likewise the knapsack sprayers to be carried on the back are useful for small areas, but they cost $10 to $15. One of these small hand sprayers is very generally useful about the garden and grounds for applying insecticides and fungicides to small trees and shrubs as well as to potatoes and other vegetables.

"When it is desired to use the same outfit for spraying in the potato field and in the orchard, a barrel spray-pump outfit (cost $10 to $20) is the proper thing to use. In the potato field this outfit may be used in two ways: First, it may be drawn through the field in a light wagon or two-wheeled cart, with a man to pump and drive while two others walk and direct the spray nozzles. This method requires much man labor and is therefore expensive, but no extra outlay for apparatus is necessary and the spraying can be done more thoroughly than by any other method practical in large fields. Second, it may be used on a one-horse two-wheeled cart, having at the rear about 9 feet of ¾-inch iron, or, better still, brass pipe, communicating with the pumps by means of a short piece of hose. To this pipe eight spray nozzles (two for each row) are attached in pairs. One man pumps and drives, spraying four rows at each passage. All things considered, this is the most satisfactory potato-spraying outfit yet devised. It can be built at a cost of $30 to $40.

"For large fields of ten or more acres geared pumps operated by horse power are entirely practical. Several good outfits of this kind are on the market. Their chief advantage over the barrel outfit last mentioned is that the labor of pumping is shifted from the driver to the horse. They have the disadvantage in

[55] For a general discussion of spraying machinery see Bulletin 243 of this Station.

being more expensive ($60 to $75), less durable and of heavier draft."

SPRAYING BEFORE RAIN.

"Some hesitate to spray potatoes when it looks like rain. They argue that the rain will wash off the bordeaux and necessitate the work being done over. Let us inquire into this matter. It is in rainy weather that spraying is most needed, because it is then that the late blight spreads most rapidly. The beating of the rain scatters the spores of the blight fungus and, the conditions for their germination being excellent, infection occurs readily. Most of the infection takes place during rainy weather. In dry weather the disease makes slow progress because the spores must have moisture in which to germinate. Moreover, much drying kills the spores outright.

"Because of these facts the best time to spray is shortly before rain. If there is sufficient time for the bordeaux to get thoroughly dry on the leaves before the rain comes, it is all right. The leaves are then protected. Spores falling on them will be unable to germinate. Even when the mixture does not get dry spraying must do some good; but in such cases another spraying should be made as soon as possible. Never stop spraying because rain threatens. On the contrary, make a special effort to get the spraying done before it rains.

COPPER SULPHATE AND COPPERAS.

"Many persons confuse copper sulphate with copperas. Copper sulphate is blue vitriol, also called blue stone. It contains copper and is used in the preparation of bordeaux mixture.

"Copperas is an entirely different thing. It is iron sulphate. It does not contain copper and cannot be used for making bordeaux.

"The crystals of the two substances are somewhat similar in appearance, but may be readily distinguished by their color. Copper-sulphate crystals are blue, while those of copperas are greenish."

ARSENITE OF SODA.

KEDZIE FORMULA.

White arsenic, pounds	2
Sal soda, pounds	8
Water, gallons	2

"Boil until the arsenic is all dissolved, which will take about fifteen minutes. Replace the water lost in boiling, as otherwise some of the material will crystalize upon cooling. This makes a stock solution of arsenite of soda, which may be placed in tightly stoppered jugs or bottles and kept on hand for use as needed. The vessels used in making and storing the solution should be plainly labeled 'Poison' and never used for any other purpose.

"Two quarts of this stock solution are equivalent to 1 pound of paris green. This is the quantity which should be used on an acre of potatoes. At the rate of 1 to 2 quarts in 50 gallons it may be used with bordeaux mixture without danger of injury to the foliage, but it must not be used alone. Even with lime water it can not be safely used at a greater strength than 1 quart of stock solution with 4 pounds of lime in 50 gallons of water."

IS IT SAFE TO PLANT WHERE POTATOES BLIGHTED THE PREVIOUS SEASON?

"The above question is often asked. The answer depends on the nature of the blight. If the blight in question is late blight, the fact the plants blighted last year has no bearing on this year's crop so far as planting on the same land is concerned. The fungus of late blight does not live over winter in the soil.[56]

"If the blight is due to the dry-rot fungus *(Fusarium oxysporum)*, or to the bacterial wilt organism *(Baccillus solancearum)*, the land should not, at once, be used for potatoes, since these diseases are harbored from year to year in the soil.

"For early blight a satisfactory answer cannot be given. The facts are not known."

BLIGHT-PROOF VARIETIES.

"While some varieties suffer more than others from both early and late blight, there are none entirely blight-proof and probably none sufficiently resistant to make spraying unnecessary. Re-

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[56] Director Woods of the Maine Station has recently advanced the opinion (Me. Exp. Sta. Bul. 112: 5) that, "Potatoes may be infected directly in the field from spores introduced in the manure, or from rotten potatoes spread upon or left in the land the preceding year." We hold that observed facts do not warrant this conclusion. In the case on which Woods bases his opinion (Loc. cit. pp. 1–2) the rotting of the tubers was probably due to infection which occurred *at the time of digging* when the tubers were brought into contact with live Phytophthora blight spores on the green tops.

sistance to blight is a desirable quality in a variety, but is less important than several other qualities. Wherever late blight occurs potatoes must be sprayed anyway, and the slight differences in the blight resistance of the different varieties does not amount to much. Most of the blight-proof varieties advertised are humbugs."

BEST TIME TO DIG BLIGHTED POTATOES.

"When potatoes are attacked by late blight there is always danger that the tubers may rot. The question is frequently asked: 'How soon after the tops begin to blight should the tubers be dug in order to avoid, as far as possible, loss from rot?' This subject has been investigated by Professor Jones at the Vermont Experiment Station (Fifteenth Annual Report, pp. 219–223), who sums up the results of his experiments[57] as follows: 'As nearly as we can formulate a rule based upon these results, it is that where there is danger of rot it is best to delay the digging some ten days or more after the tops die and that a longer delay does no harm.'

"Our own observations lead us to a similar conclusion. If the tubers are to be stored they should not be dug until the tops are dead and thoroughly dry, in order that the fungus spores may be given a chance to dry up and die. As long as the tops remain even partially green the spores of the blight fungus continue to live. In the process of digging, the tubers become covered with these live spores, and if conditions are at all favorable more or less rot results. This explains why sprayed potatoes sometimes rot more in storage than unsprayed ones.

"In this connection attention should be called to the objectionable practice of covering piles of tubers with potato tops to protect them from the sun. If the tops have been affected with late blight, they may infect the tubers and cause them to rot. The danger is especially great if the tops are green or if rain comes while the tubers are thus covered."

A PUBLIC SPRAYER.

With farm help so difficult to obtain as at present, farmers are inclined to look with disfavor upon any new method involving

[57] A later experiment giving similar results is reported in Vermont Agr. Exp. Sta. Rep. 16:161–163. See also Me. Exp. Sta. Bul. 112:2.

extra labor. This objection has been brought against potato-spraying. Farmers say, "We already have more work than we can possibly do. We can not find time to spray potatoes." The answer might well be made that the remedy lies in reducing the acreage. Twenty acres of sprayed potatoes are likely to yield more net profit than 25 acres of unsprayed potatoes and at the same time require less labor.

But there is another and more satisfactory method of solving this problem; namely, by hiring the spraying done by a public sprayer. Let some one in the neighborhood buy a sprayer and spraying materials and make a business of spraying potatoes at so much per acre. This method has several advantages. It would relieve the farmer of all bother of learning how to spray; it would make unnecessary the purchase of several expensive sprayers; by purchasing chemicals in large quantities they could be obtained at low prices; a man making spraying his business would soon become expert and able to do it better and more rapidly than the farmer could do it for himself; and the farmer would be relieved of all the extra work connected with spraying. In short, the public sprayer could spray potatoes cheaper and easier than the farmer can do it himself and make good wages at the same time.

With a good six-row, power sprayer carrying one nozzle per row, a man and team should spray 15 acres per day provided water is convenient. Making due allowance for bad weather and time lost in moving from one field to another, it would seem that one man should be able to manage at least 100 acres of potatoes, spraying them once every two weeks.

DIRECTIONS FOR SPRAYING.[58]

In general, commence spraying when the plants are six to eight inches high and repeat the treatment at intervals of 10 to 14 days in order to keep the plants well covered with bordeaux throughout the season. During epidemics of blight it may be necessary to spray as often as once a week. Usually six applications will be required. The bordeaux should contain six pounds

[58] Substantially the same as given in Bulletin 241, p. 292. The experiences of the past season do not warrant any material alteration in the recommendations there made.

of copper sulphate to each 50 gallons.[59] Whenever bugs or flea-beetles are plentiful add one pound of paris green or two quarts of arsenite of soda stock solution (See p. 190) to the quantity of bordeaux required to spray an acre.

Thoroughness of application is to be desired at all times, but is especially important when flea-beetles are numerous or the weather favorable to blight. Using the same quantity of bordeaux, frequent light applications are likely to be more effective than heavier applications made at long intervals; e. g., when a horse sprayer carrying but one nozzle per row is used, it is better to go over the plants once a week than to make a double spraying once in two weeks.

Those who wish to get along with three sprayings should postpone the first one until there is danger of injury from bugs or flea-beetles and then spray thoroughly with bordeaux and poison. The other two sprayings should likewise be thorough and applied as such times as to keep the foliage protected as much as possible during the remainder of the season. Very satisfactory results may be obtained from three thorough sprayings.

A single spraying is better than none and will usually be profitable, but more are better. Spraying may prove highly profitable even though the blight is only partially prevented. It is unsafe to postpone spraying until blight appears. Except, perhaps, on small areas, it does not pay to apply poison alone for bugs. When it is necessary to fight insects use bordeaux mixture and poison together.

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[59]For the preparation of bordeaux mixture see footnote on page 94.

EFFECT OF CERTAIN ARSENITES ON POTATO FOLIAGE.*

W. H. JORDAN, F. C. STEWART AND H. J. EUSTACE.

SUMMARY.

This bulletin gives an account of some experiments designed to determine in what extent and in what manner paris green and arsenite of lime are injurious to potato foliage.

In an experiment with paris green this well-known insecticide was applied four times by three common methods: viz., with water, with lime water and with bordeaux. Other rows received bordeaux only while still others were left untreated for a check.

At no time during the experiment, not even when the paris green was applied at the rate of $4\frac{1}{2}$ pounds per acre, was there any indication of injury to the foliage. On the contrary, the rows receiving paris green in water and also those treated with paris green in lime water were conspicuously more perfect in foliage than were the check rows. This difference was due to the partial prevention of late blight. It was shown conclusively that paris green has considerable value as a fungicide—at least one-third as much as bordeaux. Rows treated with paris green in water outyielded the check rows by 46 bushels per acre.

Rows treated with paris green in lime water yielded 12 bushels per acre less than those receiving paris green in water; but it is possible that this difference was the result of natural variation and not due to the lime.

Rows receiving paris green in bordeaux gave slightly larger yield than rows receiving bordeaux only.

In an experiment with arsenite of lime, arsenite of soda stock solution prepared by the Kedzie formula was applied with lime water and also with bordeaux. In lime water it injured the foliage severely although two pounds of quicklime were used

*A reprint of Bulletin No. 267.

for each pint of the stock solution; but in bordeaux mixture containing the same quantity of arsenite of soda solution and of lime there was no apparent injury. It is clear that arsenite of soda may be much more safely used with bordeaux than with lime water.

Rows treated with bordeaux alone outyielded rows treated with arsenite of soda in bordeaux by 34 bushels per acre. This suggests that the arsenite of soda may have been harmful although not showing any effect on the foliage. However, this is very doubtful. There is good reason to believe that, in this experiment, the foliage indications are more reliable than the yields.

The chief conclusions reached are:

(1) That paris green is not injurious to potato foliage if applied in moderate quantity with lime water or bordeaux mixture evenly distributed;

(2) That paris green has considerable fungicidal value;

(3) That arsenite of soda should not be applied to potatoes except with bordeaux mixture.

INTRODUCTION.

Certain arsenical preparations, when used as insecticides, bear an important relation to crop production in the United States. It is unquestionably true that many farm and orchard crops could not now be successfully grown in a great majority of years without some means of preventing the ravages of insect pests. This is especially true of the potato crop, because of the depredations of the Colorado beetle. That serious harm from this pest can be prevented by the use of certain arsenical compounds has been demonstrated beyond question; and when we remember that approximately 400,000 acres of potatoes are annually grown in New York, having a value of nearly $16,000,000, we realize the important place that paris green and other insecticidal preparations occupy in our farm practice.

Very much has been said in a vague way about the injuries to potatoes and other crops from the application to their foliage of arsenical compounds. Undoubtedly such injuries have occurred in many instances but whether these have been occasioned by an unavoidable effect of the arsenic compounds or whether they have been due to a misuse or injudicious application of these com-

pounds is not always clear. Within quite recent years it has been freely claimed on the part of some writers and speakers that paris green is a substance which may not be safely applied to the potato plant. There is a somewhat justifiable suspicion that these claims have not always been entirely impartial but that they have been made to some extent in the interests of non-arsenical preparations. It is worth while to determine, as a fundamental fact, whether, when properly used, paris green and other arsenic compounds are in any way deleterious to the potato plant. It is scarcely a good argument to say that this material is unsafe for use because it may be misused by unintelligent or careless farmers. There are very many utilities which would be excluded from the farm if they were to be discarded on the basis of possible misuse. The real question is, then, does paris green do the potato plant any injury when applied under proper conditions? The experiments, the results of which are given in this bulletin, were planned with a view of studying this specific question. These results are interesting and so far as a single season's observations are concerned they are conclusive.

HISTORICAL.

PARIS GREEN.

The use of paris green as an insecticide dates from some time between 1860 and 1870, soon after the Colorado potato beetle became a destructive pest in the Western States.[1] Exactly when and by whom it was first used is not known. It was early observed that some tender kinds of foliage were frequently injured by the paris green. In 1890, Gillette,[2] at the Iowa Station discovered that this injury may be avoided by using the paris green with milk of lime, or, better still, with bordeaux mixture. In 1891, Kilgore[3] at the North Carolina Station showed that the injury is due to soluble arsenic in the paris green; and that the value of lime as a preventive of the injury lies in its ability to change soluble arsenic into insoluble arsenite of lime. He also observed the insolubility of arsenites in bordeaux mixture and

[1] Lodeman, E. G. The Spraying of Plants, p. 60. The MacMillan Co. New York and London, 1899.

[2] Gillette, C. P. Experiments with Arsenites. Iowa Exp. Sta. Bul. 10: 410–413, 416. Aug., 1890.

[3] Kilgore, B. W. North Carolina Exp. Sta. Bul. 77b (Technical Bul. 2). July, 1891.

drew the conclusion: "That bordeaux mixture prevents the solubility of the arsenites and their injury to foliage by virtue of its lime." Weed[4] at the Ohio Station had previously (in 1889) pointed out the desirability of combining insecticides with fungicides.

In recent years it has been very generally advised that paris green and other arsenical insecticides be not used alone but always in combination with milk of lime or with bordeaux mixture. Most fruit growers have now adopted this method, but many potato growers still persist in using paris green alone. The potato is less liable to arsenical injury than most other plants which require spraying; but it is an indisputable fact that the use of paris green on potatoes, as practiced by farmers, often results in serious injury to the foliage. Many cases of supposed blight are nothing but paris green injury. Jones of the Vermont Station was first to direct attention to this and give a detailed description of the symptoms of arsenical poisoning. He says:[5] "The poisoning or 'burning' of potato leaves by improper applications of paris green is of more general occurrence than is commonly supposed and the resulting injuries are frequently attributed to the 'early blight' fungus. In cases of extremely strong applications of the paris green the leaves may be entirely killed or large areas 'burned' within a short time. Usually, however, its action is slower and longer continued. Its effects are then apparent as dead spots, black or brown in color, centering about flea-beetle punctures or other mutilations of the leaf. * * * These spots slowly continue to enlarge for some time and as a result of the slow death and drying of the tissues the surface of each spot is thrown into concentric elevations or ridges forming distinctly 'ringed spots.' * * * These spots so closely resemble those caused by the 'early blight' fungus that they are extremely deceptive." Continuing, he points out the symptoms by which early blight and arsenical poisoning may be distinguished. It should be noted that Jones attributes the injury to *improper* applications of paris green.

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[4] Weed, C. M. On the Combination of Insecticides and Fungicides. *Agricultural Science*, 3:263. Oct., 1889. See also Ohio Exp. Sta. Bul., Vol. II, No. 7, p. 186. Nov., 1889

[5] Jones, L. R. Potato Blights and Fungicides. Vt. Exp. Sta. Bul. 49:97. Dec., 1895.

ARSENITE OF LIME.

Excepting paris green, the most popular insecticide for use on potatoes is white arsenic applied in the form of arsenite of lime. The insecticidal properties of white arsenic have been known for more than fifty years.[6] In 1871 Saunders and Reed[7] in Canada tested it on potatoes for the Colorado potato beetle. It was mixed with flour and applied dry. The results indicated that when applied sufficiently strong to kill the beetles it caused more or less injury to the foliage. Because of its caustic properties it was rarely used until after the publication of Kilgore's formula in 1891. Kilgore recommended[8] "boiling together for one-half hour in 2 to 5 gallons of water:

1 pound commercial white arsenic
2 pounds commercial lime,

and diluting to required volume, say 100 gallons." In this way the arsenic is changed into insoluble arsenite of lime and made safer to use on foliage.

In 1897, Kedzie of the Michigan Agricultural College published what has come to be widely known as the "Kedzie[9] formula." It is essentially as follows:

White arsenic	2 pounds
Sal soda (washing soda)	8 pounds
Water	2 gallons

Boil 15 minutes or until the arsenic dissolves, leaving only a small quantity of muddy sediment. Replace the water lost in boiling. This makes a stock solution of arsenite of soda which may be placed in tightly stoppered jugs and kept on hand for use as needed. In preparing the spray mixture use two pounds of freshly-slaked lime with each pint of the stock solution in the desired quantity of water or bordeaux mixture. The arsenite of soda and the lime unite to form arsenite of lime. The arsenite in one pint of the stock solution is equivalent to four ounces of paris green.

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[6] Lodeman, E. G., Loc. cit., p. 75.
[7] Saunders, W., and Reed, E. B. *The Canadian Entomologist,* 3:46 July, 1871.
[8] Kilgore, B. W. Loc. cit., p. 7.
[9] Kedzie, R. C. *The M. A. C. Record,* March 9, 1897. A verbatim copy of this article may be found in Bulletin 152 of this Station, p. 300.

The chief advantage of this formula over the one recommended by Kilgore is that the union of the arsenic and lime is more certainly accomplished.

Both the Kilgore and the Kedzie formulas are now used to a considerable extent. Prepared by either formula, white arsenic is a cheaper poison than paris green, quite as efficient and settles to the bottom of the spray tank less readily. For these reasons it is coming into popularity with orchardists and potato growers, although its use sometimes results in injury to the foliage.

THE EXPERIMENT WITH PARIS GREEN.

PLAN AND METHODS.

The experiment included 25 rows of potatoes 290.4 feet long and three feet apart, each row having an area of one-fiftieth acre. The potatoes were of the variety Rural New Yorker No. 2. They were planted by hand May 27, 15 inches apart in the row. Each row received ten pounds of commercial fertilizer applied by hand as uniformly as possible in the furrows before planting. The potatoes came up uniformly and well making nearly a full stand of plants.

The 25 rows were divided into five series of five rows each and each series was sprayed in a different manner as follows:

Series I. Rows 1, 6, 11, 16, 21. Check. Not sprayed. Bugs hand picked,

Series II. Rows 2, 7, 12, 17, 22. Sprayed 4 times, paris green in water.

Series III. Rows 3, 8, 13, 18, 23. Sprayed 4 times, paris green in lime water.

Series IV. 4, 9, 14, 19, 24. Sprayed 4 times with paris green in bordeaux and once with bordeaux alone.

Series V. Rows 5, 10, 15, 20, 25. Sprayed five times with bordeaux alone. Bugs hand picked.

The rows of Series I received no insecticide or fungicide of any kind. As soon as Colorado potato beetles appeared they were gathered by hand. Fortunately they were less numerous than usual, making it possible to control them completely by going over the plants every other day or, at most, once a day.

The paris green was invariably used at the rate of one pound to fifty gallons of water, lime water or bordeaux as the case might be. The spraying was done thoroughly and uniformly with a knapsack sprayer, always going over the plants twice—out on one side of the row and back on the other.

First spraying.—The first spraying was made July 7. At this time the plants were 7 to 9 inches high, very vigorous and with foliage almost perfect. There were no flea-beetles and only a few colonies of newly-hatched Colorado potato beetles. Series II received paris green in water, one pound to fifty gallons; Series III, paris green in lime water prepared by mixing two pounds of freshly-slaked lime with 50 gallons of water and then adding one pound of paris green; Series IV, paris green in bordeaux at the rate of one pound to 50 gallons of bordeaux prepared by dissolving six pounds of copper sulphate in 50 gallons of water and adding lime slightly in excess of the quantity required to satisfy the yellow-prussiate-of-potash test; Series V, bordeaux only (some of the same lot as that used on Series IV, before adding paris green).

In this spraying, all mixtures were applied at the rate of 125 gallons per acre. The first rain following the spraying was a heavy shower on July 9.

Second spraying.—This spraying was made July 22. The plants were very thrifty. A few were showing blossoms. Much of the bordeaux had been washed off by rain and a large amount of new foliage had grown since the previous spraying. There were no flea-beetles. A few hills here and there were badly infested with Colorado potato beetles. Series II and III were treated exactly as in the first spraying. On Series IV and V the treatment was the same as in the first spraying except that the bordeaux was made by the 6–6–50 formula. All spray mixtures were applied at the rate of 125 gallons per acre.

In this spraying an error was made. Rows 8, 9, 10 and 11 were given the wrong treatment. This necessitates the rejection of these rows in making up the results of the experiment.

During the first night following the spraying it rained lightly all night, and on the day following there were showers alternating with periods of sunshine.

Third spraying.—The third spraying was made July 29. By this time the vines were so large that the branches of plants in adjacent rows touched. Potato beetles were well under control and there were no flea-beetles. Series II and III were again treated as in the first spraying, except that a larger quantity of spray mixture was used. On Series IV and V the treatment was the same as in the first spraying except that the bordeaux was made by the 6–4–50 formula.[10] This time all spray mixtures were applied at the rate of 175 gallons per acre. On July 31 the rainfall was .02 inch and on August 1, .52 inch.

Fourth spraying.—This spraying was made August 12. The day being bright, the spray dried on the foliage quickly. The rows of Series I, II and III were much affected with late blight. On Series III less lime was used in this spraying than in former ones, the formula this time being one pound paris green, one pound lime, fifty gallons water. The other three series were treated as in the first spraying. All applications in this spraying were at the rate of 225 gallons per acre. Following this spraying rain fell on August 13, 16, 17, 19 and 20.

Fifth spraying.—The fifth and last spraying was made August 25. There were no flea-beetles and no Colorado potato beetles. The rows of Series II and III were now so much affected by blight that it would be difficult to detect paris green injury should any occur. Consequently, there was no object in using paris green, and so it was omitted in this spraying. In spite of the frequent rains since the fourth spraying the rows of Series IV and V were still so thoroughly covered with bordeaux that they scarcely needed spraying. However, it was done with the bordeaux prepared as in the first spraying, the rate of application being 200 gallons per acre.

Chemical analysis of the paris green.—Paris green is variable in chemical composition. The greater the percentage of soluble arsenic contained in it the greater the liability of its injuring foliage.[11] Hence it is important to know the chemical composi-

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[10] Six pounds of copper sulphate, four pounds of lime and 50 gallons of water.

[11] J. K. Haywood has reported (U. S. Dept. Agr. Bureau of Chemistry Bul. 82) the results of some paris green spraying experiments which "were undertaken to show how much soluble arsenious oxide may be present in samples of paris green used for spraying purposes without injury to the foliage" of certain fruits. So far as known to the writers no such work has been done for the potato plant.

tion of of the paris green used in this experiment. It was purchased of a Geneva merchant for 16 cents per pound. Analyses made by Mr. W. H. Andrews gave the following results:

Total arsenious oxide	59.85 per ct.
Total copper oxide	27.63 per ct.

Soluble arsenic oxide obtained by treating one gram with one liter of water:

Treated 24 hours.

1st analysis	1.83 per ct.
2d analysis	2.08 per ct.
3d analysis	1.76 per ct.

Treated 10 days.

1st analysis	6.81 per ct.
2d analysis	6.81 per ct.

RESULTS.

Effect on the foliage.—Throughout the entire experiment there were no indications that the paris green caused any injury to the foliage whatever. While looking for such injury on July 9, it was observed that occasionally a leaf was affected with a trouble diagnosed as sunscald. On the tips and margins of some of the leaflets of the younger leaves there were dead, copper-colored areas one-half inch to one inch across. They were not sufficiently numerous to attract the attention of a casual observer. It is believed that they were caused by the action of the sun (on July 8) on tender, rapidly growing foliage. Certainly, the paris green had nothing to do with them, for they were quite as numerous on the check rows as on the rows treated with paris green.

The only other dead spots on the leaves were those caused by late blight, *Phytophthora infestans,* and these could be easily and positively identified by the presence of the fungus. There were no spots of early blight or anything resembling it.

Effect on late blight.—An unexpected result of the experiment was the discovery that paris green is of considerable value as a preventive of late blight, *Phytophthora infestans.* Traces of this disease were first seen on the check rows (Series I) July 23. By August 2 the rows of Series I, II and III were plainly

showing blight and there was evidently more of it on the check rows than on the adjacent rows treated with paris green in water or on those treated with paris green in lime water. Series IV and V, sprayed with bordeaux, were not affected.

On August 10 the check rows were seriously affected and the superiority of the rows treated with paris green was pronounced.

On September 8 the check rows were nearly dead from blight, while the rows receiving paris green (Series II and III) still retained about one-half their foliage and the rows receiving bordeaux (Series IV and V) were in almost full foliage. It was very plain that the application of paris green had materially checked the blight but that the bordeaux had been much more effective. The rows treated with paris green in water and those treated with paris green in lime water were equally blighted and there was no apparent difference between the rows treated with bordeaux and paris green and those treated with bordeaux alone.

On September 16, Rows 14, 15, 16, 17 and 18 were photographed (See plate XVII).[12] Row 14 (bordeaux and paris green) and Row 15 (bordeaux only) were about equal. Two-thirds of their foliage was still green. On Row 16 (check) the plants were all dead and dry over at least one-half the length of the row.[13] Row 17 (paris green in water) and Row 18 (paris green in lime water) were about equal. Both were superior to the check, but markedly inferior to the bordeaux rows Nos. 14 and 15. Most of the plants were still alive with tufts of green leaves at their tips.

Effect on the yield.—The potatoes were dug by hand on October 17 and 18. The product of each row was carefully sorted into two sizes, marketable and unmarketable, and the weight of each size taken. All tubers showing the least sign of rot were rejected. On all of the rows there was an occasional rotten tuber, but they were so few that no record of their weight was kept. Moreover, on Series I, II and III most of the affected

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[12] In order to bring out better the condition of the foliage on the different rows a white back-ground was made by sifting air-slacked lime over the ground under the plants.

[13] Row 16 fell in a dead-furrow and for that reason its yield was left out of consideration in making up the yields of the different series. However this had no bearing on the blighting of the tops. Plants are neither more nor less subject the late blight for being in a dead-furrow.

tubers were so far advanced in decay that it would have been impossible to determine their weight accurately. The yields are shown in the accompanying table:

TABLE I.—SHOWING YIELDS IN THE PARIS GREEN EXPERIMENT.

Section.	Row.	TREATMENT.	Yield per Row[14].		Yield per Acre			
			Marketable.	Small.	Marketable.		Small.	
			Lbs.	*Lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
A	1	Check. Not sprayed	215	26	179	10	21	40
	2	Paris green in water	263½	33	219	35	27	30
	3	Paris green in lime water	249	34	207	30	28	20
	4	Paris green in bordeaux	385½	22½	321	15	18	45
	5	Bordeaux only	369½	18	307	55	15	—
B	6	Check. Not sprayed	220	31	183	20	25	50
	7	Paris green in water	272	30	226	40	25	—
	8[15]	Paris green in lime water	249½	32	207	55	26	40
	9[15]	Paris green in bordeaux	375½	21½	312	55	17	55
	10[15]	Bordeaux only	400	21	333	20	17	30
C	11	Check. Not sprayed	297	21	247	30	17	30
	12	Paris green in water	279	27½	232	30	22	55
	13	Paris green in lime water	277½	31½	231	15	26	15
	14	Paris green in bordeaux	417	21	347	30	17	30
	15	Bordeaux only	380½	18	317	5	15	—
D	16[16]	Check. Not sprayed	155½	37½	129	35	31	15
	17	Paris green in water	271	42	225	50	35	—
	18	Paris green in ilme water	258	37	215	—	30	50
	19	Paris green in bordeaux	402½	20	335	25	16	40
	20	Bordeaux only	408½	26	340	25	21	40
E	21	Check. Not sprayed	195	37	162	30	30	50
	22	Paris green in water	255	35	212	30	29	10
	23	Paris green in lime water	245	38	204	10	31	40
	24	Paris green in bordeaux	382	22	318	20	18	20
	25	Bordeaux only	365	19½	304	10	16	15

[14] Length of rows, 290.4 feet.
[15] In the second spraying these rows were wrongly sprayed as follows:
Row 8. Paris green in water.
Row 9. Paris green in lime water.
Row 10. Paris green in bordeaux.
Row 11. Bordeaux only.
[16] In a dead-furrow.

As was to be expected from the condition of the foliage, the rows treated with paris green in water (Series II) and those treated with paris green in lime water (Series III) gave considerably larger yields than the check rows, while the rows receiving bordeaux mixture (Series IV and V) far outyielded all the others. Owing to an error made on Rows 8, 9, 10 and 11 in the second spraying the yields of these rows must be left out of consideration. The very low yield of Row 16 is due to its being in a dead-furrow, and so this row, also, should be rejected.

Although there was no error of any kind in connection with Rows 12, 13, 14 and 15 it is not entirely fair to use them in making up the average yields of the different series because the rejection of Row 16 leaves them without a proper check. Accordingly, Rows 8 to 16 inclusive have been omitted in preparing the following table:

TABLE II.—YIELD BY SERIES IN THE PARIS GREEN EXPERIMENT.

SERIES.	Rows.	Treatment.	Yield of marketable tubers per acre.	
			Bu.	*lbs.*
I............	1, 6 and 21......	Check; not sprayed; bugs hand picked......	175	—
II............	2, 7, 17 and 22..	Paris green in water, four times............	221	9
III...........	3, 18 and 23.....	Paris green in lime water, four times.......	208	53
IV...........	4, 19 and 24.....	Paris green in bordeaux four times and bordeaux alone once......................	325	—
V............	5, 20 and 25.....	Bordeaux alone, five times; bugs hand picked	317	30

Paris green in water increased the yield 46 *bu.* 9 *lbs. per acre.*

Paris green in lime water increased the yield 33 *bu.* 53 *lbs. per acre.*

Paris green with bordeaux increased the yield 150 *bu. per acre.*

Bordeaux alone increased the yield 142 *bu.* 30 *lbs. per acre.*

Discussion of results.—The results of this experiment do not support the belief that paris green is injurious to the potato plant. On the contrary, it appears that paris green, properly applied, may be decidedly beneficial in preventing the ravages of late blight. At no time in the course of the experiment was there any indication that paris green had injured the foliage. From August 2 until the end of the season the rows receiving paris green were conspicuously more perfect in foliage than were the rows without paris green. Likewise, the yield was in favor of the rows receiving paris green. The rows treated with paris green in bordeaux (Series IV) yielded slightly more on the average than the rows treated with bordeaux only (Series V), although the bordeaux in both cases was exactly the same. The only difference in the treatment of the two series was the use of paris green in the first four sprayings on Series IV. It is not certain that the paris green was responsible for the increased yield on Series IV, but in view of the fact that paris green has considerable fungicidal value it is not an unreasonable conclusion that such was the case. At least, the paris green did no harm.

It is worthy of note that in every section the row treated with paris green alone outyielded the adjacent row treated with paris green in lime water, the average difference being at the rate of 12 bushels, 16 pounds per acre. This difference is so small that it is not safe to base a conclusion upon it, but it suggests that the lime may have been detrimental. Of course there is no reason to believe that the lime injured the foliage. As a matter of fact there was no evidence of any injury, but it is possible that the lime counteracted the fungicidal action of the paris green. As there was no tendency to paris green injury in the experiment no benefit from the lime could be expected. Had the conditions been such as to induce paris green injury the results of the experiment would undoubtedly have been in favor of the lime. We would not discourage the use of lime with paris green when the choice lies between using the paris green alone and using it in lime water. However, we believe that the best method of all is to use the paris green always with bordeaux mixture.

That paris green possesses some value as a fungicide is not a new idea. As early as 1891 Goff[17] at the Wisconsin Station showed that apple scab may be materially checked by spraying with paris green in lime water. In experiments made by Lodeman[18] in 1892 paris green used alone reduced the injury from scab on King apples 17.7 per ct. and on Baldwins 7 per ct. The use of paris green and land plaster as a preventive of potato blight was suggested as early as 1886.[19] However, little or no attention was given the matter. The superior merits of bordeaux mixture as a fungicide have so overshadowed those of paris green that the fungicidal properties of the latter have been lost sight of completely. Time and again the statement has been made that paris green is not a fungicide. As recently as 1903, Jones and Morse[20] in discussing the results of a potato spraying experiment at the Vermont Station concluded that, "Neither paris green nor bug death used alone have any value in checking late blight."

In the experiment here at Geneva the results were so striking that there can be no doubt that paris green materially checked the

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[17] Goff, E. S. U. S. Dept. Agr. Rep. for 1891, p. 364; and Wis. Exp. Sta. Rep. 9: 264.

[18] Lodeman, E. G. Cornell Exp. Sta. Bul. 48: 272.

[19] B. F. J. in *Country Gentlemen* for May 27, 1886, p. 405; see also Lodeman, Spraying Plants, p. 98.

[20] Jones, L. R. and Morse, W. J. Vt. Exp. Sta. Rep. 16:160.

potato blight and thereby increased the yield at the rate of 46 bushels per acre. However, it should be noted that late blight was exceedingly virulent at Geneva in 1904 and that the quantity of paris green used (about 12 pounds per acre) was larger than farmers usually apply. It should be noted, also, that under parallel conditions 5 sprayings with bordeaux mixture increased the yield 142½ bushels per acre. Thus it appears that paris green has at least one-third the fungicidal value of bordeaux mixture.

Jones[21] has called attention to the fact that paris green injury is especially liable to occur where the epidermis of the potato leaf has been broken, as for example, around the punctures made by flea beetles. In this experiment there were no flea beetles, but Colorado potato beetles mutilated the leaves on some of the plants without any paris green injury resulting therefrom.

The failure of paris green to produce injury in this experiment cannot be attributed to unfavorable weather conditions. Throughout the season there was an abundance of rain which is generally regarded as favorable to paris green injury.

As previously stated, the chemical composition of paris green is variable. Some samples contain a larger percentage of soluble arsenic compounds than others and consequently some are more liable to injure foliage than are others. In some states this is regulated by law. In New York legal paris green must not contain more than 3½ per ct. of soluble arsenic compounds. Analyses made at this Station show that the great majority of the paris green offered for sale in New York complies with the law.[22] As regards the content of soluble arsenic the paris green used in this experiment is fairly representative of the paris green found on the market.

The conclusion is that paris green is not injurious to potato foliage when properly applied; that is, in moderate amount (one to two pounds per acre) with lime water or bordeaux mixture evenly distributed over the foliage.

THE EXPERIMENT WITH ARSENITE OF LIME.

PLAN AND METHODS.

This experiment included 20 rows 290.4 feet long and three feet apart, each row having an area of one-fiftieth acre. The

[21] Jones, L. R. Vt. Exp. Sta. Bul. 49: 97.
[22] See Bulletins 204 and 222 of this Station.

PLATE XVII—VIEW IN THE PARIS GREEN EXPERIMENT.

ROW 14, PARIS GREEN WITH BORDEAUX; 15, BORDEAUX ALONE; 16, CHECK; 17, PARIS GREEN IN WATER; 18, PARIS GREEN IN LIME WATER. Photographed September 16. See page ~~273.~~ 204

PLATE XVIII.—ARSENICAL INJURY TO POTATO FOLIAGE.

Bordeaux mixture superior to lime water as a preventive of such injury. Plant (at left) treated with arsenite of soda in bordeaux, uninjured; plant (at right) treated with arsenite of soda, severely injured.

PLATE XIX.—VIEW IN THE ARSENITE OF LIME EXPERIMENT.

ROW 5, CHECK; 6, ARSENITE OF SODA IN LIME WATER; 7, ARSENITE OF SODA IN BORDEAUX; 8, BORDEAUX ALONE.
Photographed September 16.

potatoes were of the variety Rural New Yorker No. 2. They were planted May 28, 15 inches apart in the row. Each row received ten pounds of commercial fertilizer applied by hand as uniformly as possible in the furrows before planting. For some reason not well understood Rows 13 to 20 inclusive did not come up as well as they should. However, there was a fair stand of plants.

The 20 rows were divided into four series of five rows each as follows:

Series I. Rows 1, 5, 9, 13, 17. Check. Not sprayed. Bugs hand picked.

Series II. Rows 2, 6, 10, 14, 18. Sprayed 4 times, arsenite of soda in lime water.

Series III. Rows 3, 7, 11, 15, 19. Sprayed 4 times with arsenite of soda in bordeaux and once with bordeaux alone.

Series IV. Rows 4, 8, 12, 16, 20. Sprayed 5 times with bordeaux alone. Bugs hand picked.

The rows of Series I received no insecticide or fungicide of any kind. Bugs were removed by hand picking as in the experiment with paris green.

The stock solution of arsenite of soda was prepared by the Kedzie formula given on page 199. In different sprayings the quantity used varied from 2 to 4 pints in 50 gallons. When used with lime water (Series II) two pounds of quicklime was added for each pint of the arsenite-of-soda solution. As in the paris green experiment, the spraying was done thoroughly, and uniformly with a knapsack sprayer.

FIRST SPRAYING.

The first spraying was made on July 7 and 8 when the plants were 6 to 8 inches high.[23] The rows of Series II were sprayed with the following mixture:—4 pints stock solution of arsenite of soda, 8 pounds quicklime and 50 gallons water. The lime was slaked slowly as for whitewash and afterward diluted to 50 gallons. The arsenite-of-soda stock solution was then added and after thorough stirring spraying was begun at once.

[23] Series IV on July 7, the other three series on July 8.

On Series III the following mixture was used: 6 pounds copper sulphate, 4½ pounds quicklime, 3 pints of the arsenite-of-soda stock solution and 50 gallons of water.[24] The copper sulphate, lime and water were first made into bordeaux mixture, the arsenite of soda then added and spraying begun at once.

On Series IV bordeaux alone was used.

In all cases the spray mixtures were applied at the rate of 100 gallons per acre.

On July 12, 1.92 inches of rain fell. The following day it was observed that the rows of Series II, sprayed with arsenite of soda in lime water, were showing spray injury. The extent of the injury was not great enough to materially affect the crop, but there was positive injury. Leaves here and there were showing dead brown areas of various shapes and sizes. Some of the spots were on the margins of the leaves and others on the interior. Certain weeds, also, were injured; namely, rough pigweed (*Amaranthus retroflexus*), yellow foxtail (*Ixophorus glaucus*) and Polygonum sp. Lamb's quarters (*Chenopodium album*) was wholly uninjured.

On the rows of Series III, where the arsenite of soda had been applied with bordeaux there was no evidence of spray injury. The check rows, also, were perfect in foliage except for traces of sunscald as in the paris green experiment (See page 203).

SECOND SPRAYING.

This spraying was made July 23 and 25.[25] Series II was sprayed with 3 pints of arsenite of soda and 6 pounds of lime in 50 gallons of water. Series III received bordeaux mixture (6–6–50 formula) with 3 pints of arsenite of soda to 50 gallons added just before spraying was begun. Series IV received only bordeaux of the 6–6–50 formula.

In this spraying all spray mixtures were applied at the rate of 150 gallons per acre.

At 4 P. M.[26] July 26 the rows of Series II, sprayed the day before, were found to be considerably injured as in the previous

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[24] This formula was used by mistake. It was intended to use 6 lbs. copper sulphate, 8 lbs. lime and 4 pints arsenite of soda in order to make this series strictly comparable with Series II.

[25] The rows of Series IV and Rows 3, 7 and 11 of Series III, were sprayed on the afternoon of July 23. It then commenced to rain and there was no opportunity to finish the spraying until July 25.

[26] There was a shower at 2 P. M.

spraying. Leaves of all ages were affected with large copper-colored dead spots, some of which closely resembled the spots of late blight (See Plate XVIII). The rows of Series III were not in the least injured.

THIRD SPRAYING.

The third spraying was made August 1. The quantity of arsenite of soda was again reduced. Series II was sprayed with 2 pints of arsenite of soda and 4 pounds of lime in 50 gallons of water, while Series III received the same amount of arsenite of soda in bordeaux made by the 6–4–50 formula. Series IV received only bordeaux of the same formula.

The rate of application was 200 gallons per acre.

But little if any injury resulted from this spraying.

FOURTH SPRAYING.

The fourth spraying was done August 12, as follows:

Series I. Check. Not sprayed.

Series II. 2 pints arsenite of soda + 4 pounds lime + 50 gallons water.

Series III. 2 pints arsenite of soda + 50 gallons bordeaux (6–4–50 formula).

Series IV. Bordeaux only (6–4–50 formula).

The rate of application was 225 gallons per acre.

On August 20 it was observed that Series II had been severely injured by the spraying, but Series III showed no trace of injury.

FIFTH SPRAYING.

The fifth and last spraying was made August 30 on Series III and IV with bordeaux only. Series II was so nearly dead from blight and spray injury that there was no object in further treatment. Probably only about one-fifth of the foliage on Series II was alive on this date. The check rows still retained about one-fourth their foliage, the remainder having been killed by blight.

On September 16, Rows 5, 6, 7 and 8 were photographed. (See Plate XIX.) Row 5 (check) and Row 6 (arsenite of soda in lime-water) were entirely dead and the stems dry. Row 7 (arsenite of soda in bordeaux) and Row 8 (bordeaux only) were equal in appearance. About three-fourths of the foliage on these rows was still green.

YIELDS.

The potatoes were dug by hand on October 22. The method of sorting and the loss from rot were the same as in the paris green experiment. (See page 204.) The yields are shown in Tables III and IV.

TABLE III.—YIELDS IN THE ARSENITE OF LIME EXPERIMENT.

Section.	Row.	TREATMENT.	Yield per Row. Marketable.	Yield per Row. Small.	Yield per Acre. Marketable.		Yield per Acre. Small.	
			Lbs.	*Lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
A	1	Check	188	51	156	40	42	30
	2	Arsenite[27] + lime water	118	59	98	20	49	10
	3	Arsenite + bordeaux	411½	40	342	55	33	20
	4	Bordeaux only	379	17	315	50	14	10
B	5	Check	162½	56	135	25	46	40
	6	Arsenite + lime water	100	47	83	20	39	10
	7	Arsenite + bordeaux	411	28	342	30	23	20
	8	Bordeaux only	414	24	345	—	20	—
C	9	Check	188	38	156	40	31	40
	10	Arsenite + lime water	111	46	92	30	38	20
	11	Arsenite + bordeaux	389	14	324	10	11	40
	12	Bordeaux only	402½	15	355	25	12	30
D	13	Check	181	39	150	50	32	30
	14	Arsenite + lime water	126½	24	105	25	20	—
	15	Arsenite + bordeaux	241	11	200	50	9	10
	16	Bordeaux only	345	9	287	30	7	30
E	17	Check	135	15	112	30	12	30
	18	Arsenite + lime water	113	25½	94	10	21	15
	19	Arsenite + bordeaux	322	10	268	20	8	20
	20	Bordeaux only	438	8½	365	—	7	5

TABLE IV.—YIELD BY SERIES IN THE ARSENITE OF LIME EXPERIMENT.

SERIES.	Rows.	Treatment.	Yield of marketable tubers per acre.	
			Bu.	*Lbs.*
I	1, 5, 9, 13 and 17	Check; not sprayed; bugs hand picked	142	25
II	2, 6, 10, 14 and 18	Sprayed 4 times, arsenite of soda in lime water	94	45
III	3, 7, 11, 15 and 19	Sprayed 4 times with arenite of soda in bordeaux and once with bordeaux alone	295	45
IV	4, 8, 12, 16 and 20	Sprayed 5 times with bordeaux alone; bugs hand picked	329	45

Arsenite of soda in lime water reduced the yield 47⅔ *bu. per acre.*
Arsenite of soda with bordeaux increased the yield 153⅓ *bu. per acre.*
Bordeaux alone increased the yield 187⅓ *bu. per acre.*

DISCUSSION OF THE RESULTS.

From the results of this experiment it appears that the use of arsenite of soda in lime water on potato foliage is attended with

[27]Arsenite of soda stock solution.

considerable risk. Injury to the foliage resulted from the use of 8 pints of arsenite of soda per acre in the first spraying and 9 pints per acre in the second and fourth sprayings. Based on the arsenic it contains, nine pints of the arsenite-of-soda stock solution are equivalent in poisoning properties to 36 ounces of paris green which is not an excessively large quantity to apply per acre. In the paris green experiment twice this amount of paris green per acre was used without the least injury to the foliage. (See pages 201, 206.)

Why injury resulted from the fourth treatment with arsenite of soda in lime water and not from the third is not clear. The spray mixture was prepared and applied in identically the same manner in both cases, except that a slightly greater quantity was used in the fourth spraying. The difference in rainfall may have had something to do with it. The third spraying was made August 1. On the night of the same day .52 inch of rain fell; an August 2, .02 inch and on August 5, .07 inch. After this there was no more rain until August 13. The fourth spraying was made August 12, following which date the rainfall was as follows: August 13, .18 inch; 16, .16 inch; 17, .31 inch; 19, .76 inch. The injury was not observed until August 20, but it is possible that it occurred earlier.

An interesting result of the experiment was the discovery of the part which copper sulphate plays, in connection with the lime, in preventing the caustic effect of the arsenite of soda. When arsenite of soda was applied with lime water injury to the foliage resulted; but when the same quantity of arsenite was applied with bordeaux mixture there was no injury. This happened three times. In the fourth spraying the quantities of arsenite, lime and water were the same in both cases the only difference being that one mixture contained copper sulphate while the other did not. The conclusion is plain that the copper sulphate was, in some way, responsible for the absence of spray injury on the rows to which it was applied. It appears that the caustic effect of the arsenite of soda is prevented more effectively by copper sulphate and lime acting together than by either one alone. In fact there is no evidence that copper sulphate alone is of any value whatever for this purpose. On the contrary it has

been shown by Gillette[28] and also by Kilgore[29] that arsenites are more injurious to foliage when applied in copper sulphate solution than when applied in water.

Heretofore, it has been supposed that bordeaux mixture prevents the caustic action of arsenites simply by virtue of the lime it contains.[30] The results of this experiment shows that not only the lime but the copper sulphate, also, is a factor in preventing injury. It is also shown that a great excess of lime in the bordeaux is unnecessary. Two pints of the arsenite of soda solution may be used safely with 50 gallons of bordeaux made by the regular 6–4–50 formula without the addition of extra lime.

The fact that Series III treated with arsenite of soda in bordeaux mixture yielded at the rate of 34 bushels per acre less than Series IV treated with bordeaux mixture alone tends to show that the addition of the arsenite was deleterious; but judgment on this point should be deferred untill further tests have been made. The yields in this experiment are not entirely reliable. The potatoes came up somewhat unevenly and some of the plants were considerably injured by Colorado potato beetles. As there was at no time any indication of arsenical injury to the foliage on Series III it is difficult to understand how the arsenite could have affected the yield.

It is advised that the arsenite of soda be used on potatoes only in combination with bordeaux mixture.

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[28] Gillette, C. P. Iowa Exp. Sta. Bul. 10: 418, 420.

[29] Kilgore, B. W. N. C. Exp. Sta. Bul. 77b (Technical Bul. 2): 9, 11.

[30] Fraser's statement (The Potato, p. 138) that, "The copper sulphate in the bordeaux mixture seems to prevent the caustic action" (of arsenite of soda), and Stewart's article on this subject (Proc. W. N. Y. Hort. Soc. 50:87) are both based on the experiment described in this bulletin.

WINTER INJURY TO FRUIT TREES.*

H. J. EUSTACE.

SUMMARY.

The cold of the winter of 1903 and 1904 was unusually severe and prolonged. The climatic conditions during the growing season of 1903 were not normal and not altogether favorable. Insects and fungus epidemics were serious upon some kinds of fruit trees. It was a combination of all of these factors that injured or killed many thousand trees, especially peach and pear.

Trunk and branch injury was most common. Root injury was not often found.

The damage was greatest in the Hudson River Valley where the cold was most severe, more than 40° below zero being reported. In the fruit growing regions of Western New York temperatures of from—10° to—15° were frequently reported. At the end of the winter the outward appearance of the trees was normal. Upon examination the bark and wood of the trunk above the snow line and of the branches were found to be discolored from black to all shades of brown.

No reliable symptom of fatal injury was found that was applicable at the end of the winter. Discoloration of the bark and wood is a symptom of injury, but not an indication of death.

Old trees did not withstand the cold, nor recover as well as young trees.

Trees died at irregular times during all of the growing season of 1904. Fruit that matured on injured trees was undersized. In proportion to the degree of injury the foliage was undersized and of abnormal color, and the usual amount of new growth was not made.

Trees and vines in low "spots" or "pockets" where the cold air settled suffered severely, as they also did on flat land where air drainage was poor.

* A reprint of Bulletin No. 269.

Difference in variety was unusually subordinate to location, age and previous health of the trees, though in many cases there was plainly a difference in the susceptibility of varieties.

Experiments indicated that, when peach trees were less than five years old, a severe pruning or cutting back to large limbs was a successful method of treating injured trees. The same treatment for older trees was a failure. Trees that did not carry any fruit made a better recovery than those that carried even a light crop.

INTRODUCTION.

The winter of 1903 and 1904 was an unusually severe one throughout New York State. In many places the temperature was the lowest on record, and the periods of extreme cold were protracted. As a result the end of the winter found many of the orchards, especially those of peaches and pears, extensively and seriously injured. Orchardists were anxious for information that would enable them to distinguish between trees fatally injured and those in which recovery was probable, and also desired to know what methods of treatment would be most likely to bring about a speedy recovery.

Reliable information upon these points was very meagre and such as was available did not well apply to the conditions as found in New York State. For these reasons and also because the opportunity was a good one it was deemed advisable to make some observations and experiments with injured trees with the hope of learning more about the subject, and to place on record facts that it is believed will be of some value should a similar disaster occur in the future.

Before a consideration of the injuries of the winter it will be necessary to review some of the unusual climatic conditions and insect and fungus epidemics of the growing season of 1903.

The climatic conditions were of the two extremes—the drought during the spring and the excessive rains of the fall—especially in the Hudson Valley. For a continuous period from "April 16 until June 10, a most severe drought occurred, during which there was no rain sufficient to benefit growing crops.[1]" Coming during these months the tax upon the vitality of all trees was

[1] New York Section of the Climate and Crop Service of the Weather Bureau. Annual Summary 1903, p. 5.

very great, but especially where the soil was shallow, or the tree was not a deep rooting one, or was young and had not become well established. Naturally the soil in many orchards became so hard that the usual and much needed spring cultivations had to be delayed, greatly to the detriment of the trees.

Following a dry September there was an excessive amount of rain during October, the precipitation being 2.78 inches more than normal—which tended to prolong the growth and prevent the wood from ripening properly before the end of the season.

The prolonged dry weather of the spring furnished favorable conditions for insect development; and several injurious species became so abundant as to cause serious epidemics, and became an important factor in maintaining even ordinary health of the trees. Upon pear trees the ravages of the psylla, *Psylla pyricola,* were extremely severe. In many orchards it was a difficult matter to save enough of the foliage to ripen the fruit; and cases were frequent where the fight against them had to be given up in despair.

The foliage of apple orchards and nursery stock was damaged by an attack of green aphis that was no less severe. During the early part of the season large amounts of foliage were destroyed or injured, the result of which could not be other than to impair greatly the vigor of the trees.

The climatic conditions and insect epidemics were further complicated and their severity increased by outbreaks of fungus diseases. Pear leaf spot, *Septoria piricola* Desm., was serious in the Hudson Valley, where unfortunately, the psylla was most severe. During the period of drought there was an exceedingly virulent outbreak in many places of the peach leaf curl, *Exoascus deformans* (Berk.) Fckl. Where spraying had not been done or had been neglected until too late to be effective, many trees lost all of their foliage, thus further taxing the vitality of the tree.

At the end of the winter it was evident that the trees most ininjured by the cold were those most seriously affected by the unusual climatic conditions and the insect and fungus epidemics. There can be little doubt but that it was a combination of the effects of the cold and unusual detrimental factors of the previous season that caused the death or injury of many

of the trees, and had it not been for these combinations the resulting damage would have been comparatively small.

OBSERVATIONS.

KINDS OF WINTER INJURY.

Winter injury is usually classified under three heads, root injury, trunk injury and branch injury. In the last class may be included the destruction of fruit buds.

Root injury, the freezing of the roots causing death or injury, occurs at times in the winter when the temperature is unusually low and the ground is bare. In some of the Western states this is a common and serious trouble, but it is unusual in New York except on very light soils and in exposed locations where the snow blows away and no mulch or cover crop is used to cover the ground and hold the snow.[2]

Trunk injury may be due to the freezing, causing death or injuries within the trunk or limbs, of the active tissue known as the cambium, a thin layer of succulent formative cells between the wood and the bark, from which new tissues are developed. When the temperature is so low as to destroy the cambium layer the tree dies. However this layer is capable of withstanding much cold and of recovering after a severe injury. It was injury of this kind that was common and serious in New York State in 1904.

Branch injury is the killing back of the new and tender wood from the tip to a definite place. This form of injury occurs to some extent every year and depends very largely upon whether the wood ripens well or grows late in the fall and contains a large amount of moisture.

HOW COLD CAUSES INJURY.

The earlier plant physiologists believed that the death of plants was caused by the water in the cells freezing and the resulting expansion bursting the cell walls, thus permanently disorganizing the tissues of the plant which resulted in its death.

Later investigations showed that this theory was incorrect, and that instead of the water freezing within the cells the cold

[2] Green, W. J., and Ballou, F. H. Winter Killing of Peach Trees. Ohio Agr. Exp. Sta. Bul. 157, p. 119.

withdrew it from them and that this withdrawal of the moisture was continuous with low temperatures and all plants that are unable to withstand this desiccation, or drying out, must ultimately be killed.

When the supply of moisture in the cells is large it is more readily withdrawn and the injury is greater. This explains why branches having an excessive amount of moisture are more readily injured or killed than those in which the moisture has been reduced by the branch ripening normally in the fall.

TEMPERATURES.

The desire to know just what minimum temperature is fatal to the various species of cultivated fruit trees has often been expressed. But it is evident that such a thing cannot be determined in any way to be of value for the reason that there are many factors other than the temperature that are highly important in connection with the low temperature, such as age of the tree, variety, previous care and health, exposure and altitude of location, character of the soil, and climatic conditions and insect and fungus epidemics during the growing season preceding the dying.

The difference in individual trees is very marked as was noticed in orchards of the same age and variety where all other conditions were as nearly parallel as could be determined, and trees that were killed stood adjacent to trees that were apparently uninjured.

However a record of the minimum temperatures in some of the important fruit sections will be interesting as evidence of what some trees have withstood and lived—some to bear crops the same year.

In the Hudson Valley the official records are as follows; the temperature in each case being the lowest recorded during the winter. Albany—24°; Athens, Greene Co.—20°; Greenwich, Washington Co.—28°; Honeymead Brook—28° and Wappingers Falls—34°, both in Dutchess Co. The following records have been reported, though not officially, for Ulster Co., Marlboro—28°; Milton—12° to—16° for high locations and—12° to—32° in hollows and valleys. In Orange Co., at Middle Hope—25° to —40°, Newburgh—26°, and Washingtonville—42°.

In the central and western part of the State the cold was not as severe, the official records being as follows: Syracuse—20°, Fayetteville, 12 miles southeast of Syracuse—29°, at Romulus, Seneca county—12°, Penn Yan, Yates county—15°, Shortsville, Ontario county—10°, Rochester—14°, Brockport, Monroe county —14° and Lockport—12°.

It seems almost impossible that peach trees could survive such low temperatures as occurred in the Hudson Valley, but the facts are that only a small percentage were killed outright, though the crop was almost a total failure. In orchards of considerable elevation and good air drainage a fair crop of fruit was harvested. Throughout the peach sections of the central and western portions of the state some trees were killed or injured so they died subsequently. The crop was a normal one, though temperatures that are commonly supposed to mean death to fruit buds existed in hundreds of orchards.

APPEARANCE OF TREES AT END OF WINTER.

At the end of the winter the external appearance of the trees was entirely normal. The bark of the trunk was smooth and of normal color and the twigs in all parts of the trees were plump and bright. Nothing about the trees looked unusual or wrong, but upon cutting into the trunk anywhere above the snow line it was found that both bark and wood were discolored for some depth into the trunk. The discoloration was most pronounced just above the snow line, and became less as the height from this point increased until on the branches in most cases the normal color and conditions, or very near them, were found.

This discoloration is due to oxidation, or the beginning of decay, and can occur only when moisture is present. It varied in intensity from black or dark brown to very light brown or what might be called a water-soaked appearance. The intensity was directly proportional to the amount of moisture in the tissue at the time of the low temperature.

Upon the discovery of this discoloration much alarm and anxiety arose. It was feared that trees showing this condition were dead, and some fruit growers removed many trees upon this supposition. It was argued that though the roots and the branches were apparently uninjured it would be impossible for the sap to

pass up from the roots, as the conducting tissue was destroyed at the point of discoloration. But observations made during the summer and fall showed these fears to be unwarranted.

Below the snow line, even a fraction of an inch, both the bark and wood were entirely normal as to color and condition. This well illustrated the great value of snow as protection against frost, and indicated that the roots were uninjured.

SYMPTOMS OF INJURY.

It was hoped that some common symptom of fatal injury caused by cold could be found—such as would enable the fruit grower to determine the condition of his trees soon after a freeze, or at the end of the winter, so that if fatally injured they could be taken out and new plantings made the same spring, thereby gaining a year in the growth of a new tree, and saving the use of the land and the expense of cultivation for a season in waiting for the injury to manifest itself during the summer.

It was at first thought that the degree of discoloration of the bark and the wood of the trunk would prove of some value in this connection, and that such trees as were badly discolored—when the bark and wood were black—could be classed as certainly dead.

To determine this point some peach and pear trees on a fruit farm in the Hudson Valley were selected and marked for examination during the growing season. These trees were of different ages and grew in a low hollow or "pocket" where the cold air settled, and the soil was moist and rich, favorable to growth late in the fall. On March 24, 1904, the condition of these was as follows: Snow line 6 to 8 inches from the ground, bark tight to the wood in all parts of the trees, though very dark brown all through, the wood black in the trunk; on the limbs the bark and wood discolored as high as a man can reach.

On September 28, 1904, the last examination of these trees was made and the conditions were found to be as follows: Trees have made a good growth of new wood and have a good crop of foliage. The bark and wood of both trunk and limbs are of normal color and condition. The discolored wood is overgrown with new wood about three-quarters of an inch thick. Many fruit buds have formed. None of the trees bore any fruit this season.

The trees marked for particular observation were in the center of an orchard of about 200 trees and the above descriptions were typical. However, it must be understood that this orchard was given good care and cultivation during the growing season.

In most of the trees there were many small twigs that had been killed, and an occasional tree on which the foliage was not of a good color. But it certainly would have been unwise to remove all of the trees in this orchard upon the supposition that they were dead because of the discoloration of the bark and wood of the trunk and limbs. This orchard and the marked trees were examined again in the early part of June, 1905. Practically every tree was in good condition, had a good crop of large and well colored foliage and a large amount of fruit.

The discoloration is, of course, a symptom of injury, and the stronger the discoloration the more severe the injury. But with peach and young pear trees the discoloration, even though very pronounced, is not a certain indication of death.

No reliable symptom of fatal injury from frost was found that was applicable at the end of the winter.

AGE OF TREES AND SUSCEPTIBILITY TO INJURY.

With peach and pear trees there was a well marked difference in the degree of injury depending upon the age of the tree.

Observations upon this point were made at many places, but most carefully upon a fruit farm of about 5,000 peach and an equal number of pear trees, at Milton, on the Hudson river, where the injury was most severe. The elevation of this farm was very uneven, varying from 200 to 500 feet above sea level, and containing many "pockets" or "hollows." The peach trees were from one to fifteen years old and the pear trees from three to twenty-five years old.

Peach trees one year set were examined in March and showed only slight discoloration of the bark and wood. Late in September, when last examined, all of these young trees were found to have made a splendid growth during the season, and a few that were cut off below the snow line to have made a vigorous growth from the stump.

Peach trees under five and six years did not show severe cases of discoloration, though it was more marked on trees in low

places where the cold settled and late growth was favored by rich moist soil. In practically all cases trees of these ages made a rapid and satisfactory recovery during the summer.

With peach trees over seven or eight years old the injury was found to be far more serious. The discoloration was much more pronounced, and increased in intensity with the age of the tree, when the other conditions were parallel, being greatest again upon trees located in low places and on moist rich soil. The older trees did not make a rapid nor vigorous recovery. The foliage was scanty, undersized and of a pale color—in contrast with the younger trees on which the foliage was normal in these respects. There were also more small dead twigs scattered through the tops of the older trees than there were in the younger trees.

Many pear trees from two to five years old were examined in which the bark and wood were badly discolored, the bark being filled with brown streaks, instead of a solid color as in the case of the peach. The common opinion was that trees in which this discoloration was marked were practically ruined, and the best way would be to cut them off below the snow line, and let them send up sprouts from the stump. If there had been time enough in the spring for the work, the owner of these trees would have treated several thousand of them in this way. But the growing season proved the fallacy of the prediction. Lack of time was fortunate for the fruit grower.

With but very few exceptions these young trees made a good recovery, had a good crop of healthy foliage, made a good amount of new wood and enlarged in the diameter of the trunk very noticeably. Wire labels loosely fastened on the trees in March had, in September, become imbedded in new growth.

All of these trees were examined again in June, 1905, and practically all of them had made a very good recovery. Nearly all of the peach trees and many of the young pear trees had a good crop of fruit.

EFFECT OF INJURY UPON TREES.

The injury manifests itself in various ways and at different times, depending upon the degree.

In some cases the trees did not show any life at the opening of spring, being killed outright during the winter. This was more

common with pear trees that were seriously affected by the psylla. The number of peach trees that died in this way was comparatively small.

In most cases some growth started in the trees, as it was able to do with the starch in the branches, but when this became exhausted in May or June and plant food was unable to come up from the roots in sufficient quantities the leaves dropped and the trees perished.

With some trees a limited amount of plant food could be forced up into the branches and here the growth continued until July or August when a few days of continuous dry, warm weather would cause the demand for more moisture than could be forced up through the injured tissues of the trunk and the tree would die.

The dying of the trees at such unusual and irregular times gave rise to much alarm among the fruit growers in some localities. It was feared that a virulent attack of the "yellows" had broken out or some new and serious disease had become prevalent.

Upon injured trees that did survive, the most striking effect of the damage was noticeable in the foliage. In proportion to the degree of damage the leaves were under normal size and not of their natural color. On some of the trees they were about one-third size, and the color was usually a pale green, though occasionally tinges of red not unlike that produced by the leaf curl disease were noticeable. This effect was so striking as to be conspicuous from a long distance. The effect was very noticeable in the amount of new growth made during the growing season. In some instances this did not exceed a few inches in length, and from this it varied up to practically the normal amount

Fruit that did mature on injured trees was under normal size for the variety. This effect was especially noticeable on peaches and pears.

ENVIRONMENT AS RELATED TO INJURY.

Altitude, air drainage and conditions of the soil had a very important bearing upon the severity of the injury. The advantages of a high altitude were best shown in some of the peach orchards in the Hudson Valley. Orchards that were located on the highest sites were injured the least of any, and many of them bore a fairly good crop of fruit. Those located on the low sites

FIG. 1.—UNPRUNED.

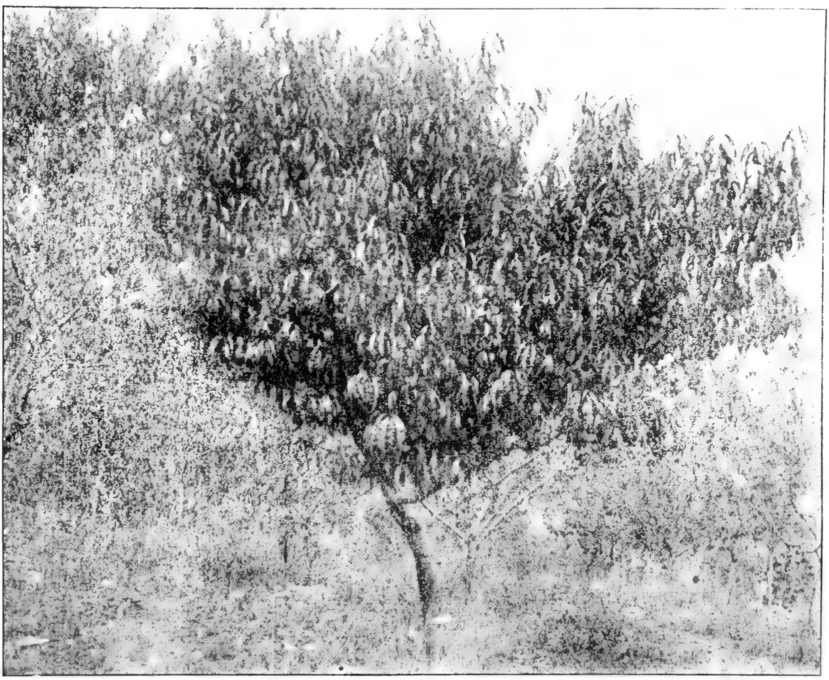

FIG. 2.—PRUNED IN APRIL.

PLATE XX.—EFFECT OF MODERATE PRUNING ON WINTER-INJURED FITZGERALD PEACH TREES.

Photographed Sept. 27.

were injured the most and none of them bore any fruit. Frequently the benefit of an elevation of a few feet was apparent. In March it was noticed that the discoloration of the bark and wood of the trunks of the trees became less intense as the altitude of the location of the tree increased.

So thoroughly has the advantage of high altitudes as sites for peach orchards been impressed upon fruit growers that many have expressed their intention of using only such sites for peach orchards in the future.

The reason for the difference in the amount and seriousness of the damage between trees and vines in low as compared with those on high sites is because the cold air rapidly passes from the high lands and settles into the lower places. This, of course, causes a very low temperature for a considerable length of time in these places, while the temperature of the high lands moderates to some extent.

Thus the factor of air drainage becomes an important one. This was strikingly brought out in an observation of the damage done to trees and vines growing in hollows or "pockets," and also upon flat lands, though of good altitude but so level as to furnish no means for the cold air to drain away. An example of the latter was found at Marlboro where all the vines in a young vineyard of Delaware grapes planted upon a very level field were killed to the snow line, but at one side of the field there was a sharp decline and the vines growing there where the cold air sank away were entirely alive. Many similar observations could be given, but this one is typical.

The great disadvantage of using hollows or "pockets" for orchards and vineyards was apparent in many places throughout the hilly fruit region of the Hudson Valley. In these places the cold air settled and remained, doing immense damage. In many of the peach orchards all of the trees in these low places were practically ruined. In a vineyard of Campbell's Early grapes at Marlboro all of the vines growing in the lowest part of a "pocket" were killed to the snow line, while none of the vines on the surrounding higher land were seriously injured.

In many of the peach orchards of Western New York there are areas of slight depression or "low spots." On these it was common to find that the trees had either been killed or were seri-

ously injured, while the surrounding trees, on land but a few feet higher, were bearing fair crops of fruit.

The explanation of this difference seems to be that the excessive amount of soil moisture in these places induced a late growth instead of the essential ripening of the wood. Further, this excessive moisture made the soil water-table high which tended to the development of shallow rooted trees, as was noticed upon the removal of many trees from these low places. Such trees very naturally, suffered more from the low temperature than the deeper rooted ones on dry or drained soil.

The difference in susceptibility to winter injury of trees growing on tile drained as compared with undrained land was seen in a peach orchard at Williamson. The trees were Elbertas, about ten years old and had always been under a high state of cultivation. In a part of the orchard the land was tile drained and in another part was undrained. The trees on the drained portion were not seriously injured and when examined the latter part of August were in a vigorous condition, while the trees on the undrained land were dead or practically ruined.

Instances of serious damage done by wind were frequently observed. Trees on the western side of exposed peach orchards where the wind had an unobstructed sweep were often killed or severely injured, while others a short distance in the orchard were not seriously damaged.

In some orchards the dead or injured trees were noticed to be confined to certain portions which indicated that the wind had blown through these places more constantly and with greater force than in other parts of the same orchard, as trees but a little distance away were not seriously damaged. Sometimes these injured portions would be an exposed corner or a more or less definitely marked path the width of several rows through the orchard.

In the Hudson Valley fruit region wind damage was apparent in peach orchards on exposed western slopes or among trees on the western crest of a hill where the force of the wind was greatest and the snow blew off.

DIFFERENCE IN VARIETY.

The difference in the susceptibility of varieties to the injury usually appeared subordinate to such other factors as location,

age and previous health and condition. However, some observations were made in orchards and vineyards where the difference in injury could be plainly seen to be due to variety.

One of the most striking differences was seen in a vineyard at Marlboro. There were two varieties, Niagara and Worden. All of the former were killed to the snow line while none of the latter seemed to be seriously injured. The vines were of the same age, and all conditions as to soil, altitude and care were the same.

Some interesting differences were seen in a peach orchard at Milton. The orchard was of 730 trees, five years old, located on an elevated site, sloping to the west. The soil was uniform and the trees had always been well cared for. A careful examination showed the following conditions:

Elberta: No fruit except a very small amount on the trees in the highest part of the orchard. Reeves Favorite: No fruit on any of the trees. Stevens *Rareripe:* Good crop of fruit on all of the trees. Bray: Some fruit but less than on the Stevens *Rareripe.*

The difference in hardiness of Baldwin, Rhode Island *Greening* and Ben Davis apple trees was seen at Marlboro. In an orchard of one year old trees of these varieties all of the Baldwin and Rhode Island *Greening* trees were killed back to within three or four feet of the ground (the trees had been about six feet high) while none of the Ben Davis trees appeared to be injured. The susceptibility of Baldwin trees to cold has also been observed by Longyear in Michigan.[3]

The following observations were made upon a farm at Middle Hope: Several hundred Lawton pear trees that had been topgrafted the previous year were killed, while adjacent trees that had not been grafted were not seriously injured. In a cherry orchard the fruit buds of Early Richmond and Montmorency were killed. The Morello trees bore a good crop. Wilson Jr. blackberry bushes were killed. Early Harvest and Eldorado blackberries had a good crop of fruit. Orange quince trees were killed to the snow line. However, they were in a low place. Chinese Cling peach trees were injured more than other varieties. Stevens *Rareripe,* Elberta, Thurber and Salway were not seriously injured.

[3] Longyear, B. O. Report of the Botanist. Michigan Board of Agr. Report 1904, p. 129.

A number of fruit growers reported the difference in varieties injured in their orchards as follows:

Peaches.—Frank L. Young, Lockport.—Globe injured the most. Late Crawford set fruit but it dropped. Early Crawford injured but little. Elberta and Stevens *Rarcripe* not injured.

C. F. Stout, Olcott.—Early varieties injured the most.

Wm. H. Outwater, Olcott.—Smock and Late Crawford injured the most.

J. O. Lockwood, Olcott.—Globe and Chair's *Choice* injured the most. Triumph, Reeves Favorite and Alexander injured the least.

James Austin, Morton.—Crawfords injured the most. Crosby the least.

I. L. Dickinson, Appleton.—Niagara injured the most, St. John next and Early Crawford the least.

Jay E. Allis, Medina.—Surprise, Orleans and Elberta injured the most. Crawfords, Niagara and Chair's *Choice* injured the least.

W. T. Mann, Barkers.—Reeves Favorite nearly all killed, Crawfords injured, Elberta not injured.

Pears.—C. G. Velie & Son, Marlboro.—Bartlett and Seckel pear trees injured the most.

A. W. K. Dick, Germantown.—Bartlett and Kieffer, injured the most. Clapp's Favorite, Anjou, Clairgeau and Seckel injured the least.

J. R. Cornell, Newburg.—Bartlett injured the most.

Apples.—A. W. K. Dick, Germantown.—Baldwin apple trees injured.

Wm. H. Hallock, Washingtonville.—Baldwin and Gravenstein apples injured the most.

Grapes.—C. G. Velie & Son, Marlboro.—Delaware grape vines very severely injured.

It will at once be seen that these reports are very contradictory and conflicting, even some from the same localities. This difference is undoubtedly due to the unlike environment, condition and age of the trees, as soil, altitude, previous care and crops; and shows very conclusively the relative unimportance of variety as compared with these other factors.

RECOVERY OF SOME TREES.

Specific mention of the recovery of some trees under observation will be interesting as showing how unreliable the early appearance of a tree is as an indication of the extent of the injury.

On the farm at Milton, previously referred to, many of the old peach trees growing in the bottoms of the "hollows" were examined in March when the bark and wood of both trunk and limbs were found to be black or very dark brown. On many of these trees the bark of the trunk could easily be pulled from the wood. They were thought to be dead beyond any question by all who examined them.

When these trees were examined in June they were in fairly good condition, there was a good crop of foliage of good size and color, and a layer of new wood had formed over the old discolored one in the trunk and limbs.

At an examination the last of September, the trees were in even better condition than in June, and a good many vigorous fruit buds had formed.

In June, 1905, most of these trees were in nearly normal condition. They had a good crop of large and strong colored foliage and a large crop of fruit.

At Marlboro, an orchard of Kieffer pear trees growing upon low ground was examined in March, and the bark and wood were discolored black all through. The trees were thought to be dead by all who examined them. Late in September these trees had a fair crop of fruit (though undersized) and the bark and wood contained many brown streaks, but had made a remarkable recovery. On one tree examined, a layer of new wood 5 millimetres thick had grown over the discolored layer.

These trees were examined again in June, 1905, and most of them found to be in splendid condition. The foliage was good size and color, a good new growth was being made and there was a large amount of fruit set.

In an orchard of Bartlett pear trees about 15 years old at Middle Hope many of the trees were considered to be ruined by all who examined them in March. In September, they were in good condition, had a good amount of foliage and a fair crop of fruit, and the old discolored wood was overgrown with a layer of new wood.

A row of young sweet cherry trees showed, when examined in March, various degrees of discoloration of the bark and wood according to the altitude. All of the trees were alive in September, and had an abundance of good foliage, had made some new growth and the wounds made in the trunk in the examinations in March had all grown over.

An orchard of Japan plums was examined in March and to every indication the trees were dead, but they ripened a fair crop of fruit, and when examined in September a thick layer of new wood and bark had covered the old discolored layer. In one tree the new wood was 8 millimetres thick and the bark 4 millimetres thick.

In all of the vineyards where vines had been killed to the snow line there was a very vigorous growth of shoots that started out from below this point. Usually there were four to ten of these shoots and many of them made a growth of fifteen feet.

TREATMENT OF INJURED TREES.

During the spring there was much demand for information as to the best way to prune injured trees so as to induce most rapid recovery. All manners of ways were advised, as cutting the young trees off below the snow line, cutting the old trees back to the large limbs or "dehorning," a moderate pruning and to do nothing at all.

As obtainable information upon this point was unsatisfactory, and not based upon actual experiments it was decided to make some experiments, to be supplemented by observations, with the hope of being able to gain some knowledge that would be useful in the future.

Upon the fruit farm previously referred to, a number of old peach trees in different orchards were cut back to where the limbs were about an inch and a half to two inches in diameter. This was done early in April. Adjacent trees, injured to the same degree, were marked and left unpruned and others pruned for comparison.

When an examination was made about the middle of June a few of these "dehorned" trees were putting out some vigorous shoots from the limbs, and the indications were that they would make a good recovery.

At an examination late in September it was very evident that this method of treatment had been a total failure. All of the trees were entirely dead or had only a few straggling leaves. The vigorous shoots that promised so well in June were all dead. The discoloration of the bark and wood was nearly the same as it was in March.

The result with old pear trees that were "dehorned" was the same as with these old peach trees; they died in the same way.

Observations made in orchards in various fruit sections of the State confirmed the results of these experiments with both peach and pear trees.

In the case of young peach trees trees the reverse seems to be true. Upon the farm of Mr. Gregory Brundage, Salisbury Mills, about ten miles from Newburg, were 5000 peach trees from 2 to 5 years old, of the following varieties: Elberta, Champion, Stevens' *Rareripe,* Clair's *Choice,* and Salway. Soon after the extreme cold of January 5 and 6, Mr. Brundage decided that the trees were seriously injured and began at once to "dehorn" them. In one orchard the work was finished in a few weeks. In the others the work was delayed until the last of March.

When these trees were examined in June they had made a splendid recovery. Many vigorous shoots had started out from the branches and there was an abundance of large well colored foliage. In some of the trees the new growth had become so thick as to require thinning.

It was very apparent that the trees cut back in January had recovered better and were making a more vigorous growth than those on which the work was delayed until March.

In one field three trees were not cut back but left for comparison. By the middle of June two of these trees were dead, the other was making a fair recovery, but the new growth was all in the top, making an undesirable tree. Three trees were hardly enough to compare with 5000 but their condition indicated that Mr. Brundage did not make a mistake in cutting these trees back.

At the time of the last examination, about the first of October, the trees had made an immense growth, more than five feet in many cases, and it was still evident that the trees cut back early were better than those cut back in March. Less than 25 trees

failed to recover, and the death of some of these is attributed to mouse injury.

These trees were carefully examined again in June, 1905. Practically all of them came through the winter in good condition notwithstanding the large amount of new wood they had. Many of the trees had a small amount of fruit.

The greatest objection to cutting back peach trees in this way is that it induces too large a growth of new wood and the tree becomes bushy. A good deal of judicious pruning is necessary to make such trees satisfactory.

These results indicate that the winter-injured trees of over seven or eight years are killed by "dehorning," while the younger trees may be treated in that way and expected to make a good recovery.

The results from a moderate pruning were encouraging in the case of both young and old peach trees. Trees adjacent to those "dehorned" were moderately pruned and marked for comparison, and others to which nothing was done were also marked. In all cases these trees were under parallel conditions and of the same age and variety.

When examined the middle of June it was plain to see that they were much superior to the trees that had nothing done to them. The foliage was much more abundant in all parts of the tree; it was larger size, and more nearly normal in color.

At the examination the latter part of September the difference was more striking than in June, for during the interval some of the unpruned trees had deteriorated, and parts of them had died.

Plate XX shows the difference fairly well on September 27, 1904. These were adjacent trees, of the Fitzgerald variety and about six years old. The tree shown in Fig. 2 was moderately pruned in April and that in Fig. 1 was unpruned.

The difference between the pruned and unpruned trees was very apparent in June, 1905. The trees that had been pruned could easily be distinguished from the others by the foliage, which was larger and better colored, by more compact tops and by larger crops of fruit.

The result was invariably the same with a large number of trees treated in this way, and the conclusion cannot be other

than that a moderate pruning of winter injured trees is much superior to no pruning, and in the case of trees over six or seven years old it means recovery where "dehorning" would be fatal.

These results confirm the reports of observations made in the Michigan peach belt the season after the severe freeze of 1899.[4]

By far the largest part of the injured trees were not pruned nor treated in any way. The conditions of these trees varied greatly. Many of them made a fair recovery, in some cases such as seemed satisfactory to the growers. But it was very apparent that the average conditions of unpruned trees as compared with those lightly pruned was that they contained a much larger amount of dead wood, and that the new growth seemed to be only at the extreme ends of the branches, which made the top of the tree too spreading.

An experiment conducted by the entomologist of this Station[5] in a peach orchard near Geneva showed a way whereby many thousand winter injured trees might have been saved. In an orchard of Fitzgerald peach trees about eight years old some were sprayed in November, 1903, with different kinds of sulphur washes, and some were left unsprayed.

In the spring it was seen that the spray mixtures had destroyed the fruit buds, for there were no blossoms upon the trees that had been sprayed, and there were upon the untreated trees. Otherwise there was no very great difference during the spring in the appearance or growth of the trees. But in July many of the untreated trees began to deteriorate rapidly, and by August many were dead and others had dropped all of their fruit and much of their foliage, while practically all of the sprayed trees remained in splendid condition and so continued during the growing season.

The greatest demand upon the vitality of the tree was made during the warm weather of July, and this together with the additional demands of the developing fruit upon the untreated trees was too great for them to overcome with their vitality already depleted from the injuries of winter.

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[4] Waite, M. B. Fruit Trees Frozen in 1904. U. S. Dept. of Agr. Bureau of Plant Industry. Bul. 51, Part III, p. 4.

[5] See Bulletin 254 of this Station, page 328.

It was evident that the loss of the crop of fruit by the destruction of the fruit buds with the spray mixture saved a good many of the trees.

Many thousand bearing peach trees, especially in Western New York orchards, died during the summer that might have been saved and enabled to make a good recovery if the crop of fruit or a part of it had been removed early in the season.

REPORT

OF THE

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[1] Died September 29, 1905. [2] Resigned May 1, 1905. [3] Resigned June 1, 1905. [4] Resigned July 1, 1905. [5] Resigned January 9, 1905. [6] Appointed May 8, 1905. [7] Appointed May 15, 1905. [8] Appointed June 1, 1905. [9] Appointed July 1, 1905.

REPORT OF THE CHEMICAL DEPARTMENT.

SOME OF THE RELATIONS OF CASEIN AND PARA-CASEIN TO BASES AND ACIDS, AND THEIR APPLICATION TO CHEDDAR CHEESE.*

L. L. Van Slyke and E. B. Hart.

SUMMARY.

1. *Object.*—The primary object of the work presented is to make a further study of the compounds first discussed in Bulletin No. 214, casein and paracasein salts of acids, with an extension to the free proteids and some of their combinations with bases.

2. *Base-Free Casein.*—Preparations of casein free from ash or nearly so were made by precipitating dilute skim-milk with acids, removing the acid and inorganic matter by repeated filtration and trituration with water in a mortar. The process required several days.

3. *Basic Calcium Casein.*—Preparations were made with base-free casein in which the proteid combined with about 2.40 per ct. of calcium oxide. One such preparation was made by triturating together calcium carbonate and the base-free casein suspended in water, and another by dissolving base-free casein in lime-water and making this neutral to phenolphthalein by acid.

4. *Neutral Calcium Casein.*—By treating base-free casein dissolved in lime-water with acid until the reaction is almost neutral to litmus, there is formed a compound of casein and calcium oxide containing about 1.50 per ct. of calcium oxide.

5. *Calcium Casein Compounds in Relation to Rennet Enzym and Soluble Calcium Salts.*—Rennet enzym coagulates neither neutral nor basic calcium casein. Neutral calcium casein after

* A reprint of Bulletin No. 261.

treatment with rennet is coagulated at ordinary temperatures by soluble calcium salts. Soluble calcium salts, as calcium chloride, coagulate both neutral and basic calcium casein on warming to 35° to 45° C.

6. *Casein Present in Milk as Neutral Calcium Casein.*—In its behavior toward soluble lime salts on warming and at ordinary temperatures after treatment with rennet, neutral calcium casein behaves like milk-casein, and casein is probably present in cows' milk as the neutral calcium casein.

7. *Identity of Base-Free Casein and the Salt-Soluble Proteid.*—A base-free casein, prepared either directly from milk or by treating a lime-water solution of free casein with an acid to the point of acidity with litmus, is readily soluble in warm 5 per ct. salt solution and in hot 50 per ct. alcohol. This body, when freshly prepared and sufficiently warmed is very plastic and ductile. It behaves in all respects like the compound which we were formerly led to regard as a compound formed by combination of casein and an acid and which we regarded as a casein mono-salt of the acid precipitant.

8. *Relation between Two Series of Compounds previously called Casein Mono-Salts and Casein Di-Salts of Acids.*—When one gram of base-free casein is treated with about .5 cc. of $\frac{n}{10}$ hydrochloric acid, a substance is formed which is insoluble in warm 5 per ct. salt solution and in hot 50 per ct. alcohol and which is no longer plastic or ductile on warming. This is like the substance usually formed when milk coagulates by natural souring. By treating base-free casein with dilute acid, it was found that one gram of base-free casein appears to combine with about .5 cc. of $\frac{n}{10}$ hydrochloric acid, forming a casein salt of hydrochloric acid. While the compounds formerly regarded by us as casein mono-salts of acids have been shown by us to be identical with base-free casein, the compounds which we called casein di-salts of acids are compounds formed by combination of acids with free casein.

9. *Paracasein and Its Compounds.*—A preparation of base-free paracasein was made, and from this dissolved in lime-water were prepared (1) basic calcium paracasein, containing in combination about 2.40 per ct. of calcium oxide, and (2) neutral calcium paracasein containing about 1.50 per ct. of combined calcium oxide.

10. *Comparison of Properties of Casein and Paracasein and their compounds. of Calcium.*—Basic calcium casein and paracasein appear soluble in water forming slightly opalescent solutions. Neither is coagulated by rennet, but both are precipitated by soluble calcium salts on warming. Neutral calcium casein is coagulated by soluble calcium salts on warming to 35° to 40° C, but not at ordinary room temperature, while neutral calcium paracasein is completely and quickly coagulated at room temperatures by soluble calcium salts. Free casein and free paracasein, freshly prepared, possess the same solubilities in warm 5 per ct. salt solution and in hot 50 per ct. alcohol; they also possess the same peculiar properties of plasticity and ductility. The close resemblance of casein and its compounds respectively to paracasein and its compounds suggests that they are chemically alike, paracasein being different only by consisting of a larger molecular aggregation than casein.

11. *Relation of Paracasein to Salt-Soluble Substance and to Body formed by Treatment with Acid.*—Free paracasein appears to be identical in characteristic properties with the compounds we formerly called paracasein mono-salts of acids used as precipitants. The compounds which we have heretofore called paracasein di-salts of acids appear to be combinations of free paracasein and acids used as precipitants, one gram of paracasein uniting, for example, with about .5 cc. of decinormal hydrochloric acid.

12. *Relation of Salt-Soluble Product of Cheese to Paracasein.*—From water-extracted fresh cheddar cheese we prepared one extract by warm 5 per ct. salt solution and another by hot 50 per ct. alcohol. These preparations have in common with free paracasein the characteristic properties of plasticity, ductility, and the same combining power with bases and acids, and therefore appear to be free paracasein instead of paracasein monolactate as we were formerly led to believe.

13. *Chemical Changes in Calcium Casein resulting from Souring of Milk or Addition of Acids.*—When an acid is formed in or added to cows' milk, the acid first combines with the bases of some of the inorganic salts of the milk and then with the calcium that is combined with the casein, resulting in the formation of a precipitate which is free casein. By further formation

or addition of acid, the free casein unites with acid, forming a casein salt of the acid, this compound, in the case of lactic acid, being the coagulum familiar in the ordinary souring of milk.

14. *Chemical Changes in Calcium Paracasein during the Process of making Cheddar Cheese.*—The coagulum, following the addition of rennet enzym to milk is calcium paracasein, either mixed or loosely combined with soluble calcium salts. While lactic acid is being formed in the process of cheese-making, it combines with the calcium of the calcium paracasein, forming free paracasein and calcium lactate. It is this free paracasein thus formed that is soluble in warm 5 per ct. salt solution and in hot 50 per ct. alcohol and possesses characteristic properties of plasticity and ductility.

15. *Suggestions in regard to the Nomenclature of Casein and Paracasein and Their Compounds.*—Much confusion prevails at present in the use of the terms casein and paracasein. It is suggested that the following nomenclature be used: (1) That the compound existing in cows' milk be called calcium casein. (2) That only the free proteid be called casein. (3) That the casein compound containing 2.40 per ct. of calcium oxide be called basic calcium casein. (4) That a compound formed by precipitation and combination with an acid be called a casein salt of the acid used. (5) That the same nomenclature be applied to the corresponding paracasein bodies, with the following addition: Calcium paracasein should be applied to the uncoagulated form and the term *coagulated* calcium paracasein to the coagulated form.

INTRODUCTION.

For several years we have been studying the chemical changes that occur in the process of cheese-ripening. Early in our work we extracted fresh and partially ripened cheese with dilute solution of sodium chloride, following a suggestion of Chittenden,[1] who has shown that, in a peptic digestion of casein, heterocaseose was formed only in small amounts. Since we obtained by our extraction with dilute salt solution amounts of proteid representing often as much as 78 per ct. of the total nitrogen present in

[1] Studies in Physiol. Chem., Yale Univ., 2:156 (1885-6).

the cheese, it became apparent that we were dealing with some compound other than heterocaseose. The first suggestion throwing any light on the method of formation of this salt-soluble substance came in the following manner: In studying the action of galactase in cheese-ripening, we made cheddar cheese from milk containing chloroform, added for the purpose of inhibiting bacterial action. Under these conditions no lactic acid was present. In order to approximate more closely the conditions present in normal cheddar cheese, we added in a parallel experiment a small quantity of lactic acid, the other conditions of experiment being kept uniform. We noticed at once that when no acid was present in the cheese, we found little or no salt-soluble substance; while in the cheese containing a little added lactic acid there were present marked quantities of the salt-soluble product. This fact suggested that lactic acid was a necessary agent in forming the salt-soluble proteid found by us in cheese. Working along the line furnished by this clue, we were led to believe that there is a chemical combination between the paracasein of fresh cheese-curd and the lactic acid formed from milk-sugar during the cheese-making process. We were able to form salt-soluble proteids also by treating paracasein with such acids as acetic, hydrochloric and sulphuric. In each case definite amounts of acid disappeared and the proteid treated with acid underwent marked and definite changes in properties. By treating the salt-soluble compound with about the amount of acid required to convert paracasein into the salt-soluble substance, we obtained a body insoluble in salt solutions and differing also in other properties. We were thus led to conclude that two sets of salts were formed by treating paracasein with acids, one containing twice as much acid in combination as the other. We therefore called the salt-soluble compound found in normal cheese paracasein monolactate, and the one insoluble in salt solution, paracasein dilactate. We also found the same behavior in the case of milk-casein when treated by acids. The two series of compounds varied in respect to many of their properties. The details of this work were described in Bulletin No. 214. Our conclusions were based upon the fact that when paracasein or casein is treated with an acid in definite quantities, we obtain compounds of definitely characteristic properties.

We desired, however, to carry our work farther, if possible, and prove beyond question that there is an actual chemical combination between acid and proteid. We desired to prepare the free proteid and then treat this with acid and study the results.

Hammarsten[2] made a special study of the question of combination between casein and acids, and concluded that there was no ground for believing that a chemical combination takes place between casein and the acid used to precipitate it. He based his statement on the fact that, by rubbing for several days in a mortar with different portions of water a precipitate formed by casein with an acid, he was able to remove the acid so completely that the remaining precipitate gave no test for acid. The substance which he used in his work was what we have called the di-acid compound of casein. In repeating Hammarsten's work, we are able to remove all traces of acid from the acid-precipitated casein by the same treatment. We are able by this process to prepare a substance free from the acids used as precipitants and also practically free from ash. We found this freshly prepared substance readily soluble in warm dilute salt solution and also in hot dilute alcohol; it also showed the ductile and plastic properties given by the substance we called a mono-salt of casein. The facts as they presented themselves to us at this point were as follows: A precipitate formed by treating milk-casein with an acid, being what we called a di-salt of casein, was by continuous washing and trituration converted into a substance free from the acid used as precipitant and nearly free from ash; the substance precipitated by acid, insoluble in dilute salt-solution and in hot 50 per ct. alcohol, was by continuous washing and rubbing converted into a substance easily soluble in warm dilute salt solution and in hot 50 per ct. alcohol. There was also a simultaneous change in other properties. In other words, what we called a di-salt of casein was changed into what we had called mono-salt of casein, but the latter instead of being combined with an acid was free from acid and ash.

In our early study we recognized in a limited way the relation of inorganic salts in milk to the neutralization of acid. In Bulletin No. 214, p. 428, we noticed that when milk, coagulated by

[2]*Maly Jahresber. d. Thierchem.*, 7:160 (1877).

rennet, is treated with varying amounts of acid, the amount of salt-soluble substance did not increase until a certain amount of acid had been used, after which it increased quite out of proportion to the increased amount of acid used. It was suggested that the formation of the salt-soluble compound did not begin until certain inorganic salts of the milk had been neutralized.

After developing the later facts described above, we proposed to study more fully the following questions:

1. What is the relation between milk-casein and the salt-soluble compound which we called a casein mono-salt?
2. What is the relation between the two series of compounds previously called casein mono-salts and casein di-salts?
3. What is the relation of casein and its derivatives to para-casein and its derivatives?

It may be well to state here, once for all, that our work deals exclusively with the casein of cows' milk and products derived from it.

THE RELATION OF MILK-CASEIN TO THE CASEIN COMPOUND SOLUBLE IN DILUTE SALT SOLUTIONS.

A study of the relation of milk-casein to the salt-soluble substance, which we have previously called a casein mono-salt, naturally resolves itself into a study of the two following questions: (1) What is milk-casein, especially in relation to inorganic compounds? and (2) What is the salt-soluble compound formed from milk-casein?

THE RELATION OF INORGANIC COMPOUNDS TO MILK-CASEIN.

Does casein, as it is found in cows' milk, exist as a free proteid or is it in some form of combination with an inorganic compound?

Hammarsten, who must be regarded as the most successful pioneer worker in this field, has not clearly and specifically stated what he considers milk-casein to be. He does not appear to make any chemical distinction between ash-free casein, as prepared from cows' milk by his well-known method, and casein as it is found in milk. He appears to favor the idea that there is in milk-casein some kind of a physical relation between the proteid and calcium phosphate, casein acting as a solvent for calcium phos-

phate.[3] Eugling[4] held that casein enters into combination with tricalcium phosphate, and the same view was held by Schaffer.[5] Söldner[6] showed that casein prepared from cows' milk can form two calcium salts, (1) a basic calcium casein, containing about 2.36 per ct. of CaO, neutral to phenolphthalein, but alkaline to litmus, and (2) a neutral calcium caesin, containing about 1.55 per ct. of CaO, slightly acid to phenolpthalein and neutral or slightly alkaline to litmus. Söldner believed that this neutral calcium casein is probably the form existing in milk, owing to its reaction and to its coagulability by rennet in the presence of soluble calcium salts. He also held that the calcium phosphate, usually found in casein precipitates, exists in a condition of suspended particles finely divided, and not in chemical combination with casein. Courant[7] confirmed the work of Söldner, calling the basic compound tri-calcium casein, and the neutral compound di-calcium casein. He also reported on rather intangible evidence a mono-calcium casein, the existence of which has not been confirmed and appears doubtful. He regards milk-casein as made up partly of di-, and partly of mono-, calcium casein. Courant's work was entirely volumetric and no attempt was made to isolate the individual compounds. Lehman and Hempel[8] regard milk-casein as a double compound formed by the combination of calcium casein and calcium phosphate.

The work done by us confirms that of Söldner. While he carried on his work mostly by volumetric methods, we have succeeded in isolating the two calcium casein compounds described by him. The details of our work follow.

Preparation of casein.—We prepared casein from cows' milk by Hammarsten's method, repeating the precipitation and solution four times. The precipitate was finally dissolved in 20 liters of very dilute ammonia water and precipitated by dilute acetic acid. The precipitate was ground in a mortar several times with water, then with alcohol, after which it was treated with ether and dried at 100° C. Thus prepared, the casein was practically ash-free,

[3] *Maly Jahresber. d. Thierchem.*, 4:146 (1874).
[4] *Landw. Versuchs-Sta.* 31:392 (1885).
[5] *Landw. Jahrb. d. Schweiz.*, 1:33 (1887).
[6] *Landw. Versuchs-Sta.*, 35:351 (1888).
[7] *Pflüger's Arch.*, 50:109 (1891).
[8] *Pflüger's Arch.*, 56:558 (1894).

containing only .042 per ct. of ash. This preparation was still slightly soluble in warm salt solution and in hot 50 per ct. alcohol.

Behavior of casein preparation toward calcium carbonate.—We rubbed in a mortar .5 gram of the casein preparation described above with finely divided calcium carbonate, suspended in water. The mixture was filtered several times through paper, giving a slightly opalescent filtrate. This solution was precipitated by 95 per ct. alcohol, the precipitate was washed several times with alcohol, then treated with ether and dried at 100° C. This preparation contained 2.46 per ct. of CaO, agreeing very closely with Söldner's work in which he showed by an indirect method that a casein preparation treated with calcium carbonate combined with 2.39 per ct. of CaO. A part of this calcium casein preparation was dissolved in dilute ammonia, reprecipitated by dilute acetic acid and the precipitate, after thorough washing and filtering, was again obtained practically ash-free.

Solubility of casein preparation in lime-water.—We dissolved 3 grams of the casein preparation in lime-water and obtained an opalescent solution.

Preparation of basic calcium casein.—The lime-water solution of casein was made neutral to plenolphthalein by $\frac{}{10}$ hydrochloric acid and became somewhat more milky. This solution, neutral to phenolphthalein, was treated with 95 per ct. alcohol, and the resulting precipitate, which readily separated, was washed several times with alcohol, finally with ether and dried at 100° C. This precipitate contained calcium chloride, either as the result of occlusion or possibly of a loose combination with the proteid. In several preparations made, calcium chloride was always present in amounts varying from .75 to 1.2 per ct. Chlorine and calcium oxide determinations were made with the following results: 1.24 grams of material yielded .0331 gram of CaO. There was present .0063 gram of Cl, equivalent to .0097 gram of $CaCl_2$ or .0047 gram of CaO. This would leave .0284 gram of CaO combined with casein, or 2.29 per ct. This preparation was therefore the basic calcium casein of Söldner. It was insoluble in 5 per ct. salt solution and in hot 50 per ct. alcohol.

Preparation of neutral calcium casein.—When a solution of casein in lime-water is made neutral to phenolphthalein, the basic calcium casein is formed, containing 2.29 to 2.46 per ct. of

CaO. When the addition of acid is carried farther, a point is reached where the solution becomes neutral to litmus and much more milky in appearance than the solution neutral to phenolphthalein. A solution of casein in lime-water was made neutral to litmus by the addition of $\frac{n}{10}$ hydrochloric acid; to this solution alcohol was added, throwing down a white precipitate. The precipitate was washed with alcohol and ether and dried at 100° C. This preparation contained 1.13 per ct. of $CaCl_2$. On analysis we found that 1.27 grams gave .0257 gram of CaO and .0093 gram of Cl (equivalent to .0072 gram of CaO,) leaving .0185 gram of CaO or 1.46 per ct. as combined with the proteid. Söldner recognized this combination and attributed to it a content of 1.55 per ct. of CaO. Another preparation contained 0.86 per ct. of $CaCl_2$ and 1.48 per ct. of CaO combined with casein.

Behavior of calcium casein solution toward rennet enzym and calcium chloride.—A solution of basic calcium casein, the compound neutral to phenolphthalein, is not coagulated by rennet enzym either in the presence or absence of soluble calcium salts, as calcium chloride. A solution of neutral calcium casein, the compound neutral to litmus, is coagulated by rennet, in the presence of soluble calcium salts. When the soluble calcium salts are removed by ammonium oxalate, no coagulation occurs. These statements are in agreement with the observations of others.

Casein present in milk as neutral calcium casein.—Our results appear to confirm in every respect the work of Söldner in regard to the relation of inorganic compounds to milk-casein. We have had the advantage of isolating the two compounds, which with him were more largely matters of inference. Of these two calcium casein compounds, the one containing about 1.55 per ct. of CaO and neutral to litmus and coagulable by rennet enzym in the presence of soluble calcium salts, appears to meet all the requirements of milk-casein. So far as our present knowledge goes, we seem to be justified in regarding milk-casein as a compound of the base calcium oxide (1.55 per ct.) and the ash-free proteid casein.

The behavior of calcium casein compounds toward soluble calcium salts.—Basic calcium casein, prepared by dissolving free casein in limewater and making neutral to phenolphthalein by acid, is coagulated by soluble calcium salts on warming to 35° to

45° C. The coagulum is insoluble in warm 5 per ct. salt solution. If any soluble calcium salts present are removed by treatment with ammonium oxalate, the basic calcium casein is not coagulated on warming. Neutral calcium casein, prepared by dissolving free casein in limewater and making neutral to litmus, is coagulated on warming by soluble calcium salts. The coagulum is insoluble in dilute salt solution. The neutral calcium casein existing in milk is coagulated on warming by a few drops of a solution of calcium chloride. If we add to milk an amount of acid insufficient to cause coagulation or to remove from its combination the calcium of the calcium casein, we can produce some coagulation on warming. This is probably due to the conversion of insoluble into soluble calcium salts, and the same result follows as when we add a soluble calcium salt directly to the milk.

The coagulation of calcium casein compounds by a soluble calcium salt may be due to purely physical change in the calcium casein compounds, or there may be a loose chemical combination between the soluble calcium salt and the calcium casein compounds, the resulting compound being insoluble in the neutral or slightly acid medium.

THE RELATION OF THE SALT-SOLUBLE COMPOUND OF CASEIN TO MILK-CASEIN.

The preparations of calcium casein, while slightly soluble in hot 50 per ct. alcohol, were insoluble in warm 5 per ct. salt solution. None of these preparations showed in any marked degree the properties of the compounds that we have called casein mono-salts. We have already called attention to the fact that, in making an ash-free preparation of casein from cows' milk we found it to be readily soluble in both warm dilute salt solution and in 50 per ct. hot alcohol. This suggested that there might be a close relation between these compounds, and we therefore made several preparations, the details of which we now give.

Preparation 1, by use of hydrochloric acid.—We diluted 2 liters of skimmed milk with 5 volumes of distilled water and warmed the mixture to 45° C. Dilute hydrochloric acid was added, accompanied by vigorous stirring to keep the precipitate in a finely divided condition. After the precipitate had settled, the supernatant liquid was poured off, the precipitate was tritu-

rated in a mortar with water and finally allowed to drain on a filter paper. It was then removed from the filter paper, mixed with water at 45° to 50° C., triturated again and filtered again. This was repeated four or five times a day and continued until the filtrate gave no test for chlorides. This required four days. When the precipitate had finally been drained, it was washed with 95 per ct. alcohol. Some of the proteid went into solution, owing to dilution of the alcohol by the water still present in the precipitate; and this partial solution stopped only after a large volume of alcohol had been used. The precipitate was finally washed with ether and dried at 100° C. The product thus prepared was a very friable white powder. It was still somewhat soluble in hot 50 per ct. alcohol and warm 5 per ct. salt solution. These solubilities are much more marked before treatment with strong alcohol and ether. The product was practically ash-free, 5.28 grams yielding an ash of ,02 per ct. The preparation was quite free from chlorides, this being shown in the following manner:—We dissolved .5 gram in hot concentrated nitric acid, to which was added a crystal of silver nitrate. The whole was boiled until complete solution of the proteid had occurred. No precipitate of silver chloride was formed.

Preparation 2, by Hammarsten's method.—We used 2 liters of skim-milk in making this preparation and followed in exact detail the method described by Hammarsten.[9] Before treatment with alcohol, this preparation was readily soluble in warm dilute salt solution and in 50 per ct. hot alcohol. It contained 1.06 per ct. of ash. It was shown to be free from acetates in the following manner:—We dissolved .5 gram in dilute sodium hydroxide, then precipitated the proteid by hydrochloric acid and filtered. The filtrate was made alkaline and evaporated to dryness. The residue gave no evidence of ethyl acetate when heated with alcohol and sulphuric acid.

Preparation 3, by use of hydrochloric acid.—We used 2 liters of skim-milk, diluting it with 15 liters of warm distilled water, and precipitating the casein by hydrochloric acid. The separated proteid was allowed to drain on filter paper and then washed with water at 45° C. It was then mixed with water and

[9] *Maly Jahresber. d. Thierchem.*, 7:159 (1877).

triturated and washed several times. The precipitate soon showed marked solubility in warm dilute salt solution and in hot 50 per ct. alcohol. The washing was continued until all chlorides were removed. The precipitate was finally washed with alcohol and ether and dried at 100° C. It was free from chlorides. Its solubility was now slight in alcohol or salt solution. The ash content was .81 per ct. We have noticed that the degree of fineness of the proteid after precipitation largely influences the ash content.

Preparation 4, by use of sulphuric acid.—The same method was followed as that described in preparation 3, except that we used sulphuric acid as the precipitant instead of hydrochloric acid. Triturating this preparation under different portions of water four or five times a day, we had to continue the operation 19 days before the filtrate failed to show the presence of sulphuric acid. A little chloroform was added from time to time to prevent bacterial action. The proteid was found to be entirely free from sulphuric acid. The extreme difficulty met in this case in removing the sulphuric acid was due to the formation of calcium sulphate in the first precipitation and to its slow solubility in water. This preparation had an ash content of .56 per ct. During the process of removing the sulphuric acid, the precipitate was readily soluble in hot 50 per ct. alcohol and in warm five per ct. solution of sodium chloride. After treatment with alcohol, these solubilities were almost entirely lost.

Preparation 5, made from lime-water solution of casein.—If we dissolve an ash-free preparation of casein in lime-water and add to this solution $\frac{n}{10}$ hydrochloric acid until blue litmus is just turned red, no visible separation of proteid occurs. If we continue to add acid, the proteid separates; and complete precipitation of the casein occurs when all the calcium in the original lime-water solution has been neutralized. This can be shown quantitatively in the following manner: Of the lime-water employed, 50 cc. required for neutralization 19.2 cc. of $\frac{n}{10}$ hydrochloric acid, using phenolphthalein as an indicator. We dissolved .5 gram of ash-free casein in 50 cc. of this lime-water. On titration, the neutral point with phenolphthalein was reached when we had used 15.2 cc. of $\frac{n}{10}$ hydrochloric acid. This means that calcium oxide, equivalent to 4 cc. of $\frac{n}{10}$ hydrochloric acid,

was no longer present as calcium hydroxide, that is, .0112 gram of calcium oxide. This amount had combined with the .5 gram of proteid, forming 2.24 per ct. of the calcium proteid compound, and this proportion indicates the basic calcium casein.

When we had added 16.4 cc. of $\frac{n}{10}$ hydrochloric acid, the solution was just blue to litmus. This indicates that calcium oxide, equivalent to 2.8 cc. of $\frac{n}{10}$ hydrochloric acid, or .00784 gram of calcium oxide, was no longer present as calcium hydroxide. This amount had combined with the .5 gram of proteid, forming 1.57 per ct. of the calcium proteid combination, and this proportion indicates the neutral calcium casein.

When we had added 16.6 cc. of $\frac{n}{10}$ hydrochloric acid to the lime-water solution of casein, litmus was turned red, but no precipitation occurred yet. After 18.5 cc of $\frac{n}{10}$ hydrochloric acid had been added, a precipitate began to form, and the precipitation of the dissolved casein was complete when we had added 19.2 cc. of $\frac{n}{10}$ hydrochloric acid, or just enough to combine with all the calcium originally present in the solution used. This work was repeated with closely agreeing results. *This precipitate is therefore base-free casein.* A preparation made in this manner and thoroughly washed showed that all the calcium present was there as calcium chloride, either occluded in the precipitate or possibly in a loose form of combination with the proteid,—in any case there was no calcium base in combination with the casein. The precipitate contained in one gram, .00343 gram of Ca and .0064 gram of Cl, which amounts agree well for the presence of calcium chloride. This body, prepared by neutralizing a solution of calcium casein, is insoluble in water but readily soluble in warm dilute sodium chloride solution and in hot 50 per ct. alcohol.

In another experiment, 25 cc. of lime-water required 10.6 cc. of $\frac{n}{10}$ hydrochloric acid to neutralize it. We dissolved in this amount of lime-water .5 gram of ash-free casein, prepared according to Hammarsten. To precipitate this amount of casein completely required 10.6 cc. of $\frac{n}{10}$ hydrochloric acid. The precipitated substance was soluble in warm dilute salt solution and in hot dilute alcohol. To this substance we added .5 cc. of $\frac{n}{10}$ hydrochloric acid and obtained a substance insoluble in warm dilute salt solution and only slightly soluble in hot dilute alcohol.

When the product made by neutralizing the lime-water solutions of ash-free casein with hydrochloric acid was dissolved in hot 50 per ct. alcohol, the dissolved proteid separated from the alcoholic solution on cooling, forming on the bottom of the beaker a gummy, sticky mass, which could easily be gathered on the end of a glass rod. When the body, freshly precipitated from its solution in lime-water, is warmed on the water-bath, it can similarly be easily gathered on a glass rod in an adherent gummy mass. When warm, it is plastic and can be drawn out in fine, long, silky threads.

Identity of base-free casein and salt-soluble body.—In the presentation of facts preceding, we have seen that when an ash-free, that is, base-free proteid, or one practically so, is prepared by precipitating milk-casein (calcium casein), with an acid, the acid precipitant being completely removed from the proteid, or by treating a lime-water solution of a base-free casein with an acid to the point of acidity with litmus, we obtain a body which is soluble in warm 5 per ct. salt solution and in hot 50 per ct. alcohol. This body, when freshly prepared and warmed, is very plastic and is capable of being drawn into very long, fine, silky threads. It behaves in all respects like the compound which we were led to regard at first as a compound formed by combination of casein and an acid, and which we regarded as a casein mono-salt of the acid precipitant. As a result of this work, we now believe that the compound formed by treating milk with an amount of acid just sufficient to combine with the calcium of the calcium casein, in addition to certain inorganic salts of the milk, is not a casein mono-salt of the acid but is base-free casein, or milk-casein (calcium casein) from which the calcium has been removed by combination with acid.

THE RELATION BETWEEN THE TWO SERIES OF COMPOUNDS PREVIOUSLY CALLED CASEIN MONO-SALTS AND CASEIN DI-SALTS.

We have already seen that when calcium casein (milk-casein) is treated with dilute acid, the base is removed from its combination with the proteid and the base-free proteid is formed, a compound corresponding in its properties to those of the compounds we formerly called casein mono-salts of acids. When to this

base-free proteid we add a dilute acid, another body appears to be formed, which is insoluble in dilute salt solution and in hot 50 per ct. alcohol and which differs also in a marked loss of the plastic properties exhibited by the base-free proteid. This is the familiar substance ultimately formed when milk is coagulated by ordinary souring or by direct addition of acids in sufficient quantity. The formation of this substance has usually been explained in two different ways: (1st) It has been quite generally held that the acid unites with the inorganic portion (calcium) of the milk-casein, thus destroying the combination, and that the free proteid then appears as solid. (2d) It has been held by some that the acid actually combines with the proteid, forming a casein salt of the acid used. According to the first explanation, only one substance is formed when milk-casein is treated with an acid, forming a precipitate, and this one substance is the base-free casein. According to the second explanation, two substances are formed, one after the other, by treating milk-casein with an acid, viz.: (1st) the base-free casein and (2d) a compound formed by the combination of the base-free casein with the acid.

Now, the existence of one body with two different sets of properties, or of two different bodies, differing in their properties, must be acknowledged, when we treat milk-casein with an acid in proper proportions. When, by treating calcium casein with a certain amount of acid, we obtain the base-free proteid and then, by treating this with an additional amount of acid, we obtain a body differing in properties from the base free proteid, the difference must either be due to chemical combination of the proteid and acid or else be the result of a purely physical change caused by the acid. Contrary to the view generally held, we have believed that there is actual combination between the proteid and acid, forming a casein salt of the acid, and this we formerly called a casein di-salt of the acid used. Since we have shown that our supposed casein mono-salts of acids are simply the base-free casein, it would appear that there is only one series of casein compounds formed by combination with acids, existing as a precipitate.

Hammarsten held that there could be no combination between the casein and acid, because by trituration with water in a mor-

tar he was able to remove the acid completely from the proteid. We have abundantly confirmed his statement that the acid can be removed from the proteid by trituration, but in view of recent developments in chemistry, this argument has no weight, since we can do the same thing in the case of some well-known and well-established inorganic salts. For example, the sulphuric acid radical of mercuric sulphate can be completely removed by trituration with water.

EXPERIMENTS SHOWING COMBINATION OF CASEIN AND ACIDS.

In order to show that there is actual combination between base-free casein and acids, we used the following method: We suspended in 50 cubic centimeters of distilled water .5 gram of finely-ground base free casein and allowed the mixture to stand one hour, with occasional shaking. At the end of this time, we added hydrochloric acid of known strength in definite quantities, after which the volume was made to 100 cubic centimeters by water and filtered. The residue was not washed. Aliquot parts of the filtrate were titrated with $\frac{n}{100}$ sodium hydroxide, using phenolphthalein as indicator. The difference between the amount of acid added and that found in the filtrate represents the amount of acid combining with the casein, plus the amount adhering mechanically to the casein. It was necessary to use dilute solutions of acid in order to avoid dissolving the proteid by an excess of acid. The materials used in this work were the four preparations of base-free casein which have been already described on pp. 247-49.

Amount of acid used kept constant in relation to proteid.—In the experiments, the results of which are given in Table I, we used different solutions of hydrochloric acid of varying dilution, but varied the quantity of acid used so that the same absolute amount of acid was used in each case, which was equal to 20 cubic centimeters of $\frac{n}{100}$ hydrochloric acid for one gram of base-free casein. The work was carried on at room temperature, 17° to 18° C.

TABLE I.—AMOUNT OF HYDROCLORIC ACID NEUTRALIZD BY ONE GRAM OF BASE-FREE CASEIN WITH CONSTANT AMOUNT OF ACID.

No. of cc. of acid used.	St'gth of acid used.	PREPARATION 1.		PREPARATION 2.		PREPARATION 3.		PREPARATION 4.	
		n-100 HCl in filtrate.	n-100 HCl in proteid.	n-100 HCl in filtrate.	n-100 HCl in proteid.	n-100 HCl in filtrate.	n-100 HCl in proteid.	n-100 HCl in filtrate.	n-100 HCl in proteid.
		cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.
40	n-200	13.6	6.4	13.6	6.4	13.8	6.2	14.0	6.0
20	n-100	13.4	6.6	14.2	5.8	14.0	6.0	14.2	5.8
16	n- 80	13.6	6.4	13.6	6.4	13.6	6.4	14.4	5.6
12	n- 60	14.0	6.0	13.6	6.4	14.0	6.0	14.0	6.0
8	n- 40	14.0	6.0	14.0	6.0	14.0	6.0	14.0	6.0
4	n- 20	13.6	6.4	14.0	6.0	14.0	6.0	14.2	5.8
Av'ge		13.7	6.3	13.8	6.2	13.9	6.1	14.1	5.9

Amount of acid used varying in relation to proteid.—In another set of experiments, we used varying quantities of acid for one gram of proteid. Otherwise the experiment was carried out like those preceding. The results are given in Table II.

TABLE II.—AMOUNT OF HYDROCLORIC ACID NEUTRALIZD BY ONE GRAM OF BASE-FREE CASEIN, THE AMOUNTS OF ACID VARYING.

No. of cc. of acid used.	Strength of acid used.	Amount of acid used equal to n-100 HCl.	PREPARATION 1.		PREPARATION 2.		PREPARATION 3.		PREPARATION 4.	
			n-100 HCl in filtrate.	n-100 HCl in proteid	n-100 HCl in filtrate.	n-100 HCl in proteid.	n-100 HCl in filtrate.	n-100 HCl in proteid.	n-100 HCl in filtrate.	n-100 HCl in proteid.
		cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.
30	n-200	15	8.8	6.2	9.2	5.8	8.6	6.4	8.8	6.2
20	n-100	20	13.6	6.4	13.2	6.8	13.4	6.6	13.6	6.4
20	n- 80	25	19.2	5.8	19.2	5.8	19.0	6.0	19.6	5.4
10	n- 60	16.6	10.8	5.8	10.6	6.0	10 8	5.8	11.0	5.6
Average.........			....	6.0	....	6.1	......	6.2	......	5.9

Amount of acid and amount of dilution varied in relation to proteid.—The amount of water in which the solid base-free casein was suspended was relatively considerable in the preceding experiments. We wished to see what difference if any, there might be when we treated the casein directly with acids of varying strength and without farther dilution. We suspended one gram of the base-free casein in each of the following amounts of solutions of hydrochloric acid: Fifty cubic centimeters of $\frac{n}{200}$, 40 cubic centimeters of $\frac{n}{100}$, 30 cubic centimeters of $\frac{n}{80}$, and 20 cubic centimeters of $\frac{n}{60}$. The mixtures were allowed to stand one hour with occasional agitation and were then filtered and

aliquot portions of the filtrate titrated as in the preceding experiments. The results are given in the following table:

TABLE III.—AMOUNT OF HYDROCHLORIC ACID NEUTRALIZED BY ONE GRAM OF BASE-FREE CASEIN, AMOUNTS AND DILUTION OF ACID VARYING.

No. of cc. of acid used.	Strength of acid used.	Amount of acid used equal to n-100 HCl.	Acid equal to n-100 HCl in filtrate.	Acid equal to n-100 HCl in proteid.
		cc.	*cc.*	*cc.*
50	n- 200	25	18.4	6.6
40	n- 100	40	33.6	6.4
30	n- 80	37.5	30.0	7.5
20	n- 60	33.3	25.6	7.7

The results in Table III indicate that when we treat the base-free casein wth a more concentrated acid solution, we have more acid left in the proteid. This is as we should expect under the conditions of experiment. The acid that is not recovered in the filtrate must either combine with the proteid or adhere to it mechanically. We made no attempt tc wash the adherent or occluded acid free from the proteid, since any thorough washing would remove some of the combined acid. Therefore, the more concentrated the acid used in treating the proteid, the more acid, as measured by titration, adhered to the proteid in addition to the fixed amount of acid that combined with the proteid, as compared with treatment with an equal volume of more dilute acid.

It is not easily conceivable that such an amount of acid as is represented by about 6 cubic centimeters of $\frac{n}{100}$ hydrochloric acid should be held only mechanically by one gram of casein, when we used solutions so dilute as those with which we worked. Bearing on this point the following additional experiments were made:

(1) We suspended a weighed amount of base-free casein in 50 cc. of water, let stand 15 minutes, added $\frac{n}{100}$ hydrochloric acid at the rate of 6 cc. for one gram of casein and made the volume to 100 cc. with water. After filtration, the filtrate was titrated and the result showed that 5.2 cc. of $\frac{n}{100}$ hydrochloric acid had been held by one gram of casein.

(2) The experiment was repeated, allowing the mixture to stand one hour after addition of acid. The result was the same as before.

(3) The experiment was repeated, except that we used only 4 cc. of $\frac{n}{100}$ hydrochloric acid for one gram of casein. The filtrate on titration showed no acid, indicating that the entire 4 cc. of $\frac{n}{100}$ hydrochloric acid had been held by the casein.

These results indicate to us that one gram of base-free casein combines with about .5 cc. of $\frac{n}{10}$ hydrochloric acid, to form a compound of casein and hydrochloric acid, and that the disappearance of acid is due to chemical union with proteid and not merely to mechanical mixture or adhesion.

The question has probably come to mind before this as to why free casein was not sooner isolated in the normal souring of milk or in the treatment of milk by direct addition of acid. It can now readily be seen why this was so. Since it requires so little acid to change the free casein into its acid combination, the point is quickly passed when we have any considerable proportion of free casein in the milk. In the normal souring of milk we were able to catch the change at a point when 65 per ct. of the casein of the milk was in the form of free casein, as shown in Bulletin No. 245, p. 12. When we use an acid to precipitate casein from milk, an excess is added, so that we get, not the free casein, but the compound formed by its combination with acid.

Summary of action of acids on milk-casein (calcium casein).—When the calcium casein of cows' milk is treated with an acid, the first reaction that takes place is a union between the acid and the calcium combined with the casein, resulting in the formation of base-free casein, a compound insoluble in water but soluble in warm 5 per ct. solution of sodium chloride and in hot 50 per ct. alcohol; a compound which also possesses the property, when warmed, of being very plastic and capable of being drawn out into long, fine, silky threads. This base-free casein is identical with the compound which we formerly regarded as being a casein mono-salt of the acid used as precipitant.

When one gram of this base-free casein is treated with an amount of acid equivalent to about .5 cc. in the case of $\frac{n}{10}$ hydrochloric acid, the properties of the casein are changed, so that it is no longer soluble in 5 per ct. salt solution and only slightly soluble in hot 50 per ct. alcohol; and, in addition, it has lost entirely its plastic properties and the power of being drawn out

into fine threads when warm. This substance we regard as resulting from the combination of acid with the base-free casein, forming a casein salt of the acid used. Our reasons for believing that there is actual chemical combination between the casein and acid are the following:

(1st) When a given amount of base-free casein is treated with an acid, a quite definite and constant amount of acid appears to be neutralized. In the case of $\frac{n}{10}$ hydrochloric acid, one gram of base-free casein appears to combine with about .5 cc. of acid.

(2d) The phenomenon of combination between proteids and acids appear to be very general, as shown by Cohnheim and others.[10]

(3d) When base-free casein is treated with an acid, it undergoes a marked change in its properties.

(4th) While the combination is comparatively weak, it appears to be as strong as in the case of some quite stable inorganic salts. The fact that the acid can be completely removed by long-continued trituration with water does not constitute an argument against combination, since some well-known inorganic salts behave the same way under similar treatment.

(5th) By treating base-free casein with a given amount of acid, we form the compound insoluble in warm dilute salt solution and hot alcohol. By removing the acid from this latter compound, we obtain again the base-free casein with a restoration of its recognized properties of solubility and plasticity. Each of these compounds can be converted into the other by addition or removal of acid.

THE RELATION OF CASEIN AND ITS COMPOUNDS TO PARACASEIN AND ITS COMPOUNDS.

The coagulum formed by the calcium casein of cows' milk when treated with rennet enzym was called by Hammarsten[11] "Käse." Schulze and Röse[12] suggested the name "paracasein" for this product and their suggestion has been very generally accepted. There is still, however, much confusion as to the exact application of this term, as we shall point out later.

[10] Chemie der Eiweisskörper, pp. 106, 114, 2d Ed. 1904.
[11] *Maly Jahresber. d. Thierchem.*, 4:138 (1874).
[12] *Landwirth. Versuchs-Sta.*, 31:131 (1884-5).

According to Hammarsten[13] and others, the action of rennet enzym on calcium casein of milk takes place in two distinct stages as follows: (1) The rennet enzym converts the milk-casein into paracasein, but there is no coagulation or change visible to the eye, the paracasein remaining in the same condition apparently as the milk-casein. In the absence of soluble calcium salts, the paracasein remains in this uncoagulated form in the case of normal milk. (2) In the second stage, coagulation or separation of the curd takes place in the presence of soluble calcium salts. The conversion of milk-casein into paracasein in the first stage is due to the rennet enzym alone, while the coagulation of the paracasein in the second stage is due to soluble calcium salts alone in the case of normal milk. The term paracasein is commonly applied to both the coagulated and uncoagulated forms.

Just what chemical change in the proteid, if any, takes place in the conversion of calcium casein into paracasein by the rennet enzym, has not been clearly demonstrated. According to Hammarsten's original theory[14] the calcium casein of the milk undergoes a hydrolytic splitting by the action of rennet enzym into two compounds: (1) A body difficultly soluble, forming the chief product and closely resembling casein in composition, *paracasein;* and (2) an easily soluble, albumose-like body, called by him *whey-proteid,* produced in very small amount. The paracasein further has not the property of holding calcium phosphate in solution to the same extent that casein has. Hammarsten[15] later modified these views, coming to the conclusion that the action of rennet enzym rearranges the casein molecule only in a physical way. Du Claux[16] regarded casein as existing in milk in three different forms in equilibrium with one another; this equilibrium could be easily disturbed by the action of acids or ferments. Coagulation, according to his theory, was a purely physical, mechanical change. A similar conclusion is held by Fuld[17], milk coagulation being regarded as a special case of the alternation between suspension and precipitation of a colloidal

[13] *Maly Jahresber. d. Thierchem.*, 2:118 (1872) and 7:158, (1877).
[14] *Maly Jahresber. d. Thierchem.*, 4:153 (1874).
[15] *Zeit. f. Physiol. Chem.*, 28:114 (1899).
[16] *Compt. Rend.*, 98:373.
[17] *Beiträge z. Chem. Physiol. und Pathol.*, 2:169 (1902).

substance. Eugling[18] concluded from work done by him that acids or rennet, when added to milk, render the insoluble calcium salts soluble and more readily available for the coagulation of the proteid. De Vries and Boekhout[19] believe that free acid exerts upon the coagulation of paracasein a direct influence in some way on its own account, independent of the formation of soluble calcium salts. Loevenhart[20] has stated that there is no chemical difference between casein and paracasein, and that observed differences in properties are due to physical changes, casein and paracasein being physical modifications of one and the same body. According to his belief, paracasein exists in larger molecular aggregations than does casein.

We thus see that, while there is a wide range of opinion in regard to the relation of casein and paracasein, there is a prevailing tendency to regard these proteids, milk-casein and paracasein, as being essentially alike in composition.

We have already referred to the circumstances which led us to regard as a mono-lactate of paracasein a body which we were able to separate from cheese by means of a warm 5 per ct. salt solution. We have indicated how we came to regard the substance formed from this body by treatment with lactic acid as paracasein dilactate. We have in the preceding pages shown how we now regard the corresponding casein compounds. It is now our purpose to consider in a similar manner paracasein and some of its compounds, and we shall present our discussion in the following order:

1. The relation of inorganic compounds to paracasein.
2. The relation of the salt-soluble compound of paracasein to paracasein.
3. The relation between the two series of compounds previously called paracasein mono-salts and paracasein di-salts.
4. The relation of casein and its compounds to paracasein and its compounds.

THE RELATIONS OF INORGANIC COMPOUNDS TO PARACASEIN.

In order to study paracasein in its relations to calcium and to acids, it was essential to obtain a paracasein that should be prac-

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[18] *Landwirth. Versuchs-Sta.*, 31:392 (1885).
[19] *Landwirth. Versuchs-Sta.*, 55:221 (1901).
[20] *Zeit. Physiol. Chem.*, 41:177 (1904).

tically base-free. Preparations made by coagulating cows' milk with rennet and washing the coagulum are high in ash content, containing often 4 or 5 per ct.; moreover, such preparations still contain the calcium originally combined in the calcium casein of the milk and are not satisfactory for such work as we desired to do. We therefore made a preparation of paracasein as follows:

Preparation of paracasein.—To one liter of skim-milk, we added 1.25 grams of ammonium oxalate; the milk, after standing a short time, was filtered through paper. To 500 cc. of this filtrate we added .05 cc. of Hansen's rennet extract and kept the whole at a temperature of 37° C. for two hours. A small amount of thymol was added. To show that the rennet enzym had acted upon the calcium casein in the milk, we took 10 cc. of the treated milk, cooled to room temperature, and added two drops of a 10 per ct. solution of calcium chloride. In a few minutes the milk had formed a firm coagulum, which indicated that the rennet enzym had functioned and produced paracasein. The 500 cc. of treated milk we now diluted with 16 liters of warm, distilled water and added dilute hydrochloric acid until the proteid had separated. This precipitation was accompanied by vigorous stirring to keep the proteid as finely divided as possible, thus facilitating the removal of inorganic salts. After the precipitate had settled, the supernatant liquid was removed, the precipitate was filtered and then triturated with warm water and filtered, the trituration and filtering being repeated until all trace of chlorides was removed, which required four days. The precipitate after removal of acid was soluble in warm 5 per ct. salt solution and in hot 50 per ct. alcohol. Finally, the preparation was washed with strong alcohol and ether and dried at 100° C. This treatment greatly lessened its solubility in dilute salt solution and alcohol. It was nearly ash-free, containing 0.11 per ct. and gave no test for chorides when boiled with nitric acid and silver nitrate.

Solubility of paracasein preparation in lime-water.—The paracasein, prepared in the manner described, was soluble in lime-water, forming a solution having a dull, opalescent appearance.

Preparation of basic calcium paracasein.—We dissolved about two grams of our paracasein preparation in lime-water and made the solution neutral to phenolphthalein by addition of $\frac{n}{100}$ hydrochloric acid. The solution became more milky in appearance but no precipitation was observable. This solution was now precipitated by alcohol, filtered, washed several times with alcohol, finally with ether and dried at 100° C. The preparation was insoluble in dilute salt solution and practically so in hot dilute alcohol. Determinations of calcium and chlorine gave the following results: One gram contained a total of .0283 gram of CaO, and .0063 gram of Cl (equivalent to .0047 gram of CaO combined as calcium chloride). Deducting the calcium oxide equivalent, present as chloride, from the total, we have .0236 gram, which represents the amount of calcium oxide combined with the proteid, or 2.36 per ct. This preparation therefore corresponds very closely in its calcium content, with the basic calcium casein. As in the case of the calcium casein preparations, all the calcium paracasein preparations contained calcium chloride.

Preparation of neutral calcium paracasein.—When we treat a lime-water solution of paracasein with an amount of acid sufficient to turn blue litmus red, or just a little short of this, the proteid separates as a precipitate and this occurs before all the calcium of the original lime-water solution has been neutralized. This product is insoluble in dilute salt solution and nearly insoluble in hot dilute alcohol. The product was thrown on a filter and washed several times with water. Filtration was rather slow. The precipitate was then washed with alcohol and ether and dried at 100° C. Determinations of calcium and chlorine gave the following results: One gram contained .0391 gram of ash, a total lime content of .0194 gram of CaO and .0064 gram of Cl (equivalent to .0048 gram of CaO combined as calcium chloride). Deducting the CaO equivalent, present as chloride, from the total CaO, we have .0146 gram, which represents the amount of calcium oxide combined with the proteid or 1.46 per ct. This preparation therefore corresponds closely to the neutral calcium casein.

We have seen above that the neutral calcium paracasein. formed by making a lime-water solution of paracasein neutral

to litmus by acid, separates as a precipitate, while neutral calcium casein does not separate thus. At the point of neutrality with litmus, the body formed, that is, neutral calcium paracasein is precipitated. *In this respect and in this respect only does there appear to be a marked difference between the properties of casein and paracasein compounds.* This is right in harmony with what takes place when rennet acts on milk in the presence of soluble calcium salts,—an insoluble calcium paracasein is formed. This shows that our preparation of paracasein had not reverted to casein.

Preparation of base-free paracasein.—In 50 cc. of lime-water, requiring 21.1 cc. of $\frac{n}{10}$ hydrochloric acid for neutralization, we dissolved .5 gram of our ash-free paracasein preparation. The solution became neutral to phenolphthalein after the addition of 16.9 cc. of $\frac{n}{10}$ hydrochloric acid. This leaves calcium oxide equivalent to 4.2 cc. of $\frac{n}{10}$ hydrochloric acid as combined with the proteid or .01176 gram of CaO, which is 2.35 per ct. of the paracasein, and this is the basic calcium paracasein.

When 18 cc. of $\frac{n}{10}$ hydrochloric acid had been added, a precipitate began to separate, but the solution was still alkaline to litmus. When 18.5 cc. of the acid had been added, precipitation was complete. This leaves calcium oxide equivalent to 2.6 cc. of $\frac{n}{10}$ hydrochloric acid as combined with the proteid, or .00728 gram of CaO, which is 1.46 per ct. of the paracasein, and this is the neutral calcium paracasein.

When 21.1 cc. of $\frac{n}{10}$ hydrochloric acid had been used, an amount necessary to neutralize exactly the lime-water used for dissolving the paracasein, the proteid was still precipitated. It was now quite easily soluble in warm 5 per ct. salt solution and readily so in hot 50 per ct. alcohol. On warming, the precipitate separated on the bottom of the beaker and was easily gathered in a mass on a stirring rod. This mass was very plastic, showing a tendency to flow when kept warm; it also possessed the property of being drawn into long, fine, silky threads. It behaved in every respect like *base-free casein.*

In another experiment, we dissolved 1.5 grams of our paracasein preparation in lime-water and then exactly neutralized the solution with $\frac{n}{10}$ hydrochloric acid. The precipitated proteid was washed with alcohol and ether and dried at 100° C. Deter-

minations of calcium and chlorine showed their presence in the proportions found in calcium chloride, which was probably held mechanically in the proteid mass.

Behavior of lime-water solutions of paracasein compounds towards rennet and soluble calcium salts.—Basic calcium paracasein, prepared by dissolving base-free paracasein in lime-water and making neutral to phenolphthalein, is not coagulated by rennet in the presence or absence of soluble calcium salts. However, a solution of basic calcium paracasein may be coagulated on warming by soluble calcium salts alone without rennet.

Neutral calcium paracasein, prepared by dissolving base-free paracasein in lime-water and making neutral to litmus, is coagulated readily at room temperature or on warming by soluble calcium salts, with or without rennet, but not in the absence of soluble calcium salts.

Rennet changes calcium casein to calcium paracasein but does not coagulate the proteid. Soluble calcium salts coagulated neutral calcium paracasein and the action takes place through quite a range of temperature; while basic calcium paracasein is coagulated by soluble calcium salts only after warming. Here, as in the case of the corresponding calcium casein compounds, the coagulation may be the result of purely physical change or there may be a loose combination between the soluble calcium salt and the calcium paracasein compound.

Summary of results of work done on paracasein and its compounds.—We have made and studied the following paracasein preparations: (1) Base-free paracasein, the free proteid; (2) basic calcium paracasein, containing about 2.40 per ct. of calcium oxide, and (3) neutral calcium paracasein, containing about 1.50 per ct. of calcium oxide.

THE RELATION OF THE SALT-SOLUBLE COMPOUND OF PARACASEIN TO PARACASEIN.

Of the three paracasein preparations made and studied by us, we have found only one that was readily soluble in warm 5 per ct. salt solution and hot 50 per ct. alcohol, and this was the base-free paracasein. This body on warming also showed the peculiar plastic property and the power of being drawn into long, fine, silky threads, which are shown by the salt-soluble substance pre-

pared by us from cheese-curd and cheese. This is the body which our former work led us to regard as a compound formed by combination of paracasein and lactic acid in the case of cheese and which we regarded as paracasein monolactate. As the result of our more recent work, we now believe that the compound formed by treating calcium paracasein (cheese curd) with an amount of acid just sufficient to combine with the calcium of the calcium paracasein, in addition to certain inorganic salts held mechanically in the cheese-curd, is not paracasein monolactate but base-free paracasein, or calcium paracasein from which the calcium has been removed by its combination with acid.

THE RELATION BETWEEN THE TWO SERIES OF COMPOUNDS PREVIOUSLY CALLED PARACASEIN MONO-SALTS AND PARACASEIN DI-SALTS.

When to the base-free paracasein we add dilute acid, another body appears to be formed, which differs in properties from the base-free proteid in being insoluble in warm 5 per ct. salt solution and hot 50 per ct. alcohol, and also in possessing none of the peculiar plastic properties of the base-free paracasein. This substance is formed when milk is treated with rennet enzym and allowed to coagulate either by spontaneous souring or by the direct addition of dilute acids. We at first regarded this substance as a paracasein di-salt of an acid, but since we have shown that what we regarded as a paracasein mono-salt is the base-free proteid, paracasein, we now regard this compound as resulting from the combination of acid with the base-free paracasein, forming a paracasein salt of the acid used, corresponding to the casein salts of acids, which have been already discussed.

In each of several experiments we suspended in distilled water portions of .5 gram of base-free paracasein and treated this with varying amounts of dilute acid of different strengths, agitating from time to time for an hour. The mixture was filtered and the filtrate titrated with $\frac{n}{100}$ hydrochloric acid. The amount of acid not recovered in the filtrate is regarded as representing approximately the quantity that had combined with the paracasein. This was found to be equivalent to about 0.5 cc. of $\frac{n}{10}$ hydrochloric acid, closely agreeing with the results obtained by treating base-free casein with acid.

THE RELATION OF CASEIN AND ITS COMPOUNDS TO PARACASEIN AND ITS COMPOUNDS.

We have made preparations of the following compounds, which have been described in the preceding pages:

Casein, the base-free proteid or uncombined proteid.

Basic calcium casein, containing the free proteid combined with about 2.40 per ct. of CaO.

Neutral calcium casein, containing the free proteid combined with about 1.50 per ct. of CaO.

Casein salts of acids, formed by combination of the free proteid with acids.

Paracasein, the base-free or uncombined proteid.

Basic calcium paracasein, free paracasein combined with about 2.40 per ct. of CaO.

Neutral calcium paarcasein, free paracasein combined with about 1.50 per ct. of CaO.

Paracasein salts of acids, formed by combination of the free proteid with acids.

A comparison of the properties of casein and paracasein and their compounds strongly suggests that they are chemically alike, paracasein and its combinations being larger molecular aggregations than casein and its corresponding combinations, in accordance with the suggestion of Loevenhart. The following statements serve to bring out the close resemblance more strikingly.

(1) The free proteids, casein and paracasein, possess the same solubilities in warm 5 per ct. salt solution and hot 50 per ct. alcohol. They possess the same peculiar plastic properties when warmed and show the same power of being drawn out in fine, silky threads.

(2) Casein and paracasein form compounds containing the same amounts of combined calcium oxide.

(3) Casein and paracasein, when treated with dilute acid in the proportion of one gram to about .5 c.c. of $\frac{n}{10}$ hydrochloric acid, are changed into bodies having the same properties, which differ strikingly from the properties of the free proteids.

(4) Neither basic calcium casein nor basic calcium paracasein is coagulated by rennet, either in the presence or absence of soluble calcium salts. Basic calcium casein and basic calcium

paracasein are both coagulated when warmed to 35° to 45° C. in the presence of soluble calcium salts, but not in the absence of soluble calcium salts.

(5) Neutral calcium casein (present in milk) is coagulated by a few drops of a soluble calcium salt on warming; and neutral calcium paracasein (present in milk acted upon by rennet enzym) is coagulated at ordinary temperatures by soluble calcium salts. Neither neutral calcium casein nor neutral calcium paracasein is coagulated by rennet in the absence of soluble calcium salts.

(6) Neutral calcium casein, prepared by making a lime-water solution of free casein neutral to litmus, is an opalescent solution, free from any visible suspended particles; neutral calcium paracasein, prepared by making a lime-water solution of free paracasein neutral to litmus, is a clearly defined coagulum. In this respect only does there appear to be any marked difference in the behavior of the neutral calcium compounds of casein and paracasein. Here the difference is one rather of degree than of kind, since neutral calcium casein is coagulated by small amounts of soluble calcium salts on warming, while neutral calcium paracasein is coagulated at lower temperatures by soluble calcium salts.

THE RELATION OF THE SALT-SOLUBLE PRODUCT IN CHEESE TO PARACASEIN.

It was from our work with cheese (American cheddar) that we gained the first suggestion which led us to investigate this field. It is desirable, therefore, that we should now, if possible, establish the relation between the salt-soluble, alcohol-soluble body obtained from cheese, which we were first led to regard as paracasein monolactate and the paracasein compounds we have prepared from milk and discussed in the preceding pages.

We have established the fact that fresh cheddar cheese contains a large percentage of its proteid in the form of a body soluble in warm five per ct. salt solution and in hot 50 per ct. alcohol. Weidmann[21] dissolved from emmenthaler cheese by hot alcohol a substance called by him caseoglutin. Röse and Schulze[22] made a quite extensive study of the properties of this

[21] *Landwirtsch. Jahrb.*, 1882, p. 587.
[22] *Landwirth. Versuchs-Sta.*, 31:130 (1884-5).

body, but reached no definite conclusions as to whether it was an individual compound or what was its relation to cheese-ripening. Winterstein[23] has studied the cleavage products of caseoglutin treated by concentrated hydrochloric acid and finds the proteid bases arginine and lysine present in proportions differing from the amounts obtained by Hart[24] from casein. The results of his work cannot be regarded as conclusive, since variation of conditions in producing cleavage leads to quite variable results. A cleavage study made by us on a similar product suggests a close relation between casein and the salt-soluble product, which appears to be identical with caseoglutin. (Bulletin 214, p. 63, 1902.)

PREPARATION OF CHEESE EXTRACTS.

Material used to furnish preparation.—We used as the source of our material in making preparations for study a cheddar cheese one day old, which indicated by its stringing on a hot iron an abundance of salt-soluble substance. Portions of the cheese were ground in sand and extracted with water at 50° C. The portion insoluble in water was then divided, part to be extracted with hot 50 per ct. alcohol and part with warm 5 per ct. salt solution.

Preparation made by extraction with alcohol.—The ground, water-extracted cheddar curd was treated with boiling 50 per ct. alcohol. The extract was filtered through paper on a hot-water funnel. The filtrate on cooling and standing deposited the extracted proteid in a rubber-like mass. This mass was ground up in water several times, filtered, washed with 95 per ct. alcohol and ether, and dried at 100° C. The product was a hard mass, difficult to pulverize. It contained 1.40 per ct. of ash.

Preparation made by extraction with 5 per ct. solution of sodium chloride.—The remaining portion of ground, water-extracted cheese was extracted with a 5 per ct. solution of sodium chloride at 60° C., filtered through paper twice and then precipitated with two volumes of 95 per ct. alcohol. On standing over night the precipitate separated. It was filtered, washed by decantation with water several times to remove the salt and finally thrown on a filter paper and washed until all sodium

[23] *Zeit. f. Physiol. Chem.*, 41:487 (1904).
[24] *Zeit. f. Physiol. Chem.*, 33:347 (1900).

chloride was removed. The precipitate was then washed with alcohol and ether, and dried at 100° C. The product was easily powdered. It contained 1.37 per ct. of ash.

BEHAVIOR OF SALT-SOLUBLE AND ALCOHOL-SOLUBLE PREPARATIONS TOWARD LIME WATER.

We made a study of the power of these two preparations to combine with calcium in comparison with base-free casein, in order to ascertain whether they were base-free or not. Our method was the following: In portions of 50 cc. each of lime water of known strength, we dissolved .5 gram each of base-free casein, of the salt-soluble preparation and of the alcohol-soluble preparation. These lime-water solutions of proteids were then treated with $\frac{n}{10}$ hydrochloric acid until the solution was neutral to phenolphthalein, with the following results:

TABLE IV.—POWER OF DIFFERENT PREPARATIONS TO COMBINE WITH CALCIUM.

	n-10 HCl required to neutralize.	Difference of n-10 HCl between lime-water and solutions of proteids in lime-water.	Equivalent to CaO combined with proteid.	Per ct. of CaO combined with proteid.
	cc.	*cc.*	*Gram.*	Per ct.
50 cc. lime-water	19.5	—	—	—
.5 gram of base-free casein dissolved in 50 cc. lime-water	15.5	4	.01120	2.24
.5 gram of alcohol preparation dissolved in 50 cc. lime-water	15.4	4.1	.01148	2.29
.5 gram of salt-soluble preparation dissolved in 50 cc. lime-water	15.6	3.9	.01093	2.19

These results show that the salt-soluble and alcohol-soluble preparations made from cheese possessed the same power of combining with calcium as did casein or paracasein known to be base-free, and that they must therefore have been base-free proteids capable of forming a calcium combination equivalent to that of basic calcium casein or paracasein. These preparations from cheese appear therefore to be identical with base-free paracasein.

The calcium of the ash present was evidently not a part of the proteid molecule but was probably an impurity of calcium lactate or possibly this salt loosely combined with the proteid, appearing on ignition as calcium phosphate.

BEHAVIOR OF SALT-SOLUBLE AND ALCOHOL-SOLUBLE PREPARATIONS TOWARD ACIDS.

In determining the amount of acid that could combine with these salt-soluble and alcohol-soluble preparations made from cheese, we used the methods already employed in connection with casein and paracasein. We suspended .5 gram of proteid in water, added 10 cc. of $\frac{n}{100}$ hydrochloric acid, made the volume to 100 cc. filtered, and titrated the filtrate with $\frac{n}{100}$ sodium hydroxide, with phenolphthalein indicator. The results, figured on the basis of one gram of proteid, were as follows:

TABLE V.—ACID COMBINING POWER OF DIFFERENT PREPARATIONS.

MATERIAL USED.	Amount of acid used equal to n-100 HCl.	Acid equal to n-100 HCl in filtrate.	Acid equal to n-100 HCl in proteid.
	cc.	*cc.*	*cc.*
Base-free casein	20.0	13.6	6.4
Alcohol-soluble preparation	20.0	13.6	6.4
Salt-soluble preparation	20.0	14.0	6.0

In respect to the power of combining with acids, these results indicate that the alcohol-soluble and salt-soluble preparations made from cheese are essentially the same compounds as casein and paracasein, that is, that they are essentially base-free paracasein.

THE NOMENCLATURE OF CASEIN AND PARACASEIN AND THEIR COMPOUNDS.

From the work presented in the preceding pages, there is reason to believe that there exist the following bodies, representing milk-casein and paracasein and the compounds formed by them:

Casein, the base-free proteid or free casein.

Basic calcium casein, containing free casein combined with about 2.40 per ct. of CaO.

Neutral calcium casein, calcium casein containing about 1.50 per ct. of CaO in combination, probably identical with casein as it exists in cows' milk.

Casein salts of acids, compounds existing as precipitates and formed by combination of the free proteid with acid.

Paracasein, the base-free proteid formed by treating calcium casein with rennet enzym.

Basic calcium paracasein, containing free paracasein combined with about 2.40 per ct. of CaO.

Neutral calcium paracasein, calcium paracasein containing about 1.50 per ct. of CaO in combination, probably identical with the uncoagulated body present in cows' milk treated with rennet enzym in the absence of soluble calcium salts.

Paracasein salts of acids, compounds existing as precipitates and formed by combination of the free paracasein with acid.

In most of the literature on the subject, the word casein is used indiscriminately to mean milk-casein, free casein, or those casein salts formed by acid precipitation. In many cases it is used comprehensively to include all the proteids in cows' milk. A similar state of confusion exists in regard to the use of the word paracasein. It would therefore seem pertinent to make the following suggestions, tentatively at least, in regard to the nomenclature of these compounds:

(1) That the word *casein* be applied only to the *free proteid,* that is, the *base-free casein.*

(2) That the *compound existing in cows' milk* and commonly called casein be called *calcium casein.*

(3) That the casein *compound* containing about *2.40 per ct. of CaO* be called *basic calcium casein.*

(4) That a compound formed by precipitation and combination with an acid be called a casein salt of the acid used.

(5) That the same nomenclature be applied to the corresponding paracasein bodies, simply substituting the word paracasein for casein, with the following addition: Calcium paracasein should be applied to the uncoagulated substance produced in milk by rennet enzym, while the coagulum of this substance caused by soluble calcium salts should be called *coagulated* calcium paracasein.

THE RELATION OF THE RESULTS TO CERTAIN CHANGES TAKING PLACE DURING THE CHEESE-MAKING PROCESS.

In the manufacture of cheddar and similar types of cheese, after the addition of rennet enzym, and coagulation, there takes place a progressive change, resulting in the production of increased amounts of a proteid soluble in warm 5 per ct. solution

of sodium chloride. This product may amount in fresh cheese to 75 to 80 per ct. of the proteids present. We were led by our former work to interpret these facts as follows: Lactic acid, formed by the lactic fermentation of milk-sugar, combines with the paracasein of the curd, forming paracasein mono-lactate, insoluble in water but soluble in warm dilute salt solution and in hot 50 per ct. alcohol. In the light of the results of our more recent work, this interpretation must be modified and the observed facts appear to be explained correctly in the following manner: The coagulum following the addition of rennet enzym to milk is calcium paracasein, either mixed or loosely combined with soluble calcium salts. While lactic acid is being formed in the cheese-making process, it combines with the calcium of the calcium paracasein, forming free paracasein and calcium lactate. The conditions of manufacture are so controlled that normally not enough acid is produced to convert all the calcium paracasein to base-free paracasein. The proteids of the curd are therefore a mixture, in varying proportions, of calcium paracasein and free paracasein. It is the free paracasein that is soluble in warm 5 per ct. salt solution and in hot 50 per ct. alcohol; and it is this body that has the characteristic property of being drawn out in fine, silky threads, when touched with a hot iron. It is the free paracasein that imparts to cheese curd its peculiar plastic and ductile properties, exhibited in the process known as "packing" or "matting." It is the free paracasein, therefore, that appears to be the body in which begin to take place the various chemical changes grouped under the general term cheese-ripening.

When, in the process of cheese-manufacture, an excess of lactic acid is produced, as 0.7 or 0.8 per ct., we have the product familiarly known as cottage or Dutch cheese. This product is of a loose, granular structure and is insoluble in warm salt solution. In this case all the calcium of the calcium paracasein combines with lactic acid, after which additional amounts of free lactic acid formed unite in a loose combination with the free paracasein producing paracasein lactate, which differs from free paracasein in a most marked manner in respect to its solubilities in dilute salt solution and hot alcohol, its plasticity and its ability to form fine strings when heated.

THE PROTEIDS OF BUTTER IN RELATION TO MOTTLED BUTTER.*

L. L. VAN SLYKE AND E. B. HART.

SUMMARY.

1. *Points investigated.*—The questions studied in this bulletin are: (1) The relation of casein compounds to cream-ripening; (2) casein compounds present in butter and buttermilk; (3) the relation of casein compounds to mottled butter.

2. *Casein compounds in ripened cream.*—In ordinary methods of cream-ripening, neither calcium casein nor free casein is present, but only casein lactate, when the lactic acid is allowed to exceed .5 per ct. Casein lactate is the substance most familiar as curdled sour milk.

3. *Casein compounds in butter and buttermilk.*—When the amount of lactic acid in cream exceeds .5 per ct., the casein in the butter and buttermilk is present as casein lactate. In butter and buttermilk made from so-called sweet cream, we usually find calcium casein and some free casein, and on standing for some weeks these may be changed in the butter into a mixture of free casein and casein lactate or wholly into casein lactate.

4. *Views commonly held in respect to cause of mottled butter.*—It has been quite universally believed that the light spots or streaks in butter, known as mottles, are caused by the uneven distribution of salt, the more concentrated brine deepening the yellow color of the fat, and the lighter portions being the unsalted or lightly salted areas.

5. *Points studied in relation to mottled butter.*—The investigation covered the following conditions in relation to the mottling of butter: (1) Richness of cream, (2) degree of ripeness of cream, (3) temperature of churning, (4) size of butter-granules, (5) temperature of wash-water, (6) working of butter.

*A reprint of Bulletin No. 263.

6. *Results of investigation of preceding conditions.*—When the churning was managed so as to make the butter-granules of the size of rice-grains and these were carefully washed twice with water below 45° F., removing most of the buttermilk adhering to the outer surface of the granules, no mottles were obtained, however conditions were varied in other respects. Mottles were always found when the buttermilk was not sufficiently removed.

7. *Relation of proteïds to mottled butter.*—The amount of proteid (casein lactate) in mottled butter is greater in the light portions than in the darker portions, and is the cause of the lighter color of the mottles.

8. *Relation of salt to mottles.*—(1) Salt brine does not change in any way the color of butter-fat. (2) Salt brine, as it commonly occurs in butter, has the power of hardening and localizing the proteid particles, the action requiring several hours for completion. (3) Butter, free from buttermilk adhering to the outer surface of the granules, does not produce mottles when salted, whether the salt is evenly or unevenly distributed. (4) Mottles do not occur in unsalted butter. (5) In mottled butter, the light portions usually contain less salt than the darker portions.

9. *Cause of mottled butter.*—Mottles in butter are due, primarily, to the presence and uneven distribution of buttermilk adhering to the outer surface of the small granules; and, secondarily, to the hardening and localizing effect of salt brine upon the proteid of the buttermilk thus retained in butter. The light portions of mottled butter owe their lighter color to the presence of localized proteid (usually casein lactate). The yellow or clear portions occur where the spaces between the butter-granules are filled with clear brine and are comparatively free from casein compounds. Several hours are required to complete the action of the brine upon the proteid of the butter.

10. *Prevention of mottles in butter.*—Mottles in butter can be prevented by avoiding those conditions that retain buttermilk in the butter and observing those conditions that favor the removal of buttermilk from butter-granules before salting. The butter-granules should be about the size of rice-grains and should be washed twice with water at a temperature of 35° to 45° F.

INTRODUCTION.

In connection with our study of the action of acids upon milk-casein (calcium casein), it occurred to us that the results might have an application in some of the stages of butter-making. We have clearly established the fact that two distinct substances are found in succession when calcium casein is brought into contact with an acid, whether it be the lactic acid produced in milk by the fermentation of milk-sugar, or some other acid such as acetic, hydrochloric or sulphuric. When a small amount of acid is added to milk or to a preparation of calcium casein, a precipitated substance unlike calcium casein is formed, this substance being soluble in warm 5 per ct. solution of sodium chloride and also in hot 50 per ct. alcohol, and possessing characteristic properties of plasticity and ductility. This substance we were at first led to regard as a compound formed by direct combination of casein and acid and we called it a casein mono-salt of the acid used as precipitant; but we have recently shown (Bulletin No. 261) that the compound is base-free casein.

When this body is treated with an additional amount of acid a substance is formed which is insoluble in warm 5 per ct. salt solution and nearly so in hot 50 per ct. alcohol and which has lost the plastic and ductile properties that characterize free casein.

This substance we formerly regarded as a casein di-salt of the acid used to form it, in the belief that there were two series of precipitated salts formed by casein with an acid. Since our later work shows that there is only one series, this substance we now regard as simply a casein salt of the acid used as precipitant.

The compound we formerly designated as casein monolactate is free casein or simply casein, and the body we previously called casein dilactate is casein lactate.

Since the presence of one or both of these compounds is necessarily involved in all operations where milk undergoes the change of ordinary souring, it seemed desirable to make a special study of the following points: (1) What, if any, relation these compounds might have to the ripening of cream, preliminary to butter-making; (2) which of these compounds is commonly present in butter and buttermlik; and (3) whether the occur-

rence of what is known as "mottling" in butter has any relation to either of these casein bodies.

THE RELATION OF CASEIN AND CASEIN LACTATE TO CREAM-RIPENING.

We wished first to ascertain what form of casein compound was obtained in the ripening of cream, when the cream showed different percentages of acid. Three series of experiments bearing on this point were made. Some fresh, pasteurized cream was treated with a carefully prepared starter in Erlenmeyer flasks, stoppered with cotton. These were allowed to stand at room temperature, samples being withdrawn for examination from time to time. The results of these experiments are given in the following table:

TABLE I.—SHOWING CHEMICAL CHANGES IN CREAM-RIPENING.

No. of experiment.	Age of cream when analyzed.	Amount of milk sugar in cream.	Amount of milk sugar changed.	Amount of milk acid formed.	Total amount of nitrogen in cream.	Nitrogen in cream in form of casein and its compounds.	Nitrogen in cream in form of casein lactate.
	Hours.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	Fresh	3.64	———	0.15	0.39	0.32	0.00
1	8	3.58	0.06	0.18	0.39	0.31	———
1	24	2.92	0.72	0.60	0.38	0.33	0.33
1	32	2.90	0.74	0.61	0.39	0.30	0.30
1	48	2.88	0.76	0.62	0.39	0.32	0.32
1	72	2.90	0.74	0.63	0.38	0.34	0.34
2	Fresh	3.84	———	0.14	0.41	0.34	0.00
2	24	3.04	0.80	0.64	0.40	0.35	0.35
3	Fresh	3.81	———	0.14	0.41	0.35	0.00
3	24	2.93	0.88	0.70	0.40	0.36	0.36

The following statements are suggested by the data contained in Table I:

(1) *Nitrogen compounds in ripened cream.*—When the cream was fresh and when it was eight hours old, there was only calcium casein (milk-casein) present, that is, neither of the compounds (free casein and casein lactate), formed from calcium casein by treatment with lactic acid, was present. In 24 hours the only casein compound present in the cream was casein lactate, the compound insoluble in warm dilute salt solution; this is the compound commonly observed in milk curdled by ordinary souring. In each of these experiments the cream had curdled

completely to a definite coagulum. It would therefore appear that in ordinary methods of cream-ripening, when the lactic acid is allowed to reach 0.6 per cent., neither calcium casein nor free casein is present, but only casein lactate, the substance most commonly observed as curdled sour milk.

(2) *Decrease of milk-sugar in cream ripening.*—In the three experiments the milk-sugar decreased to an extent varying from 0.72 to 0.88 per ct. in 24 hours. In the first experiment, which was continued 72 hours, the amount of milk-sugar decreased very little after 24 hours.

(3) *Formation of lactic acid in cream-ripening.*—When the cream was fresh, the apparent amount of lactic acid was only 0.14 or 0.15 per ct., which increased in 24 hours to 0.6 to 0.7 per ct. In the first experiment, which was continued 72 hours, the acid increased very little after 24 hours.

In connection with these experiments it may be mentioned that, in several lots of cream ripened so as to show an acidity of .38 to .43 per ct., we found much free casein and little casein lactate.

THE ACIDITY OF MILK AND CREAM.

It may be well in this connection to call attention to the inaccuracy involved in attributing the acidity of milk or cream to lactic acid alone. The usual method of determining acidity in milk or cream is to titrate a given amount of milk with a standardized solution of fixed alkali, using phenolphthalein as indicator, the alkali being added to the milk until a fairly permanent pink color appears. Lactic acid is not the only compound in milk that neutralizes alkali. It is well known that strictly fresh milk which contains no lactic acid, neutralizes an appreciable amount of alkali. The compounds in fresh milk or cream that have the power of neutralizing alkali are the following: (1) Calcium casein (milk-casein), (2) acid phosphates and citrates, and (3) carbon dioxide. Of these, the calcium casein and acid phosphates appear to be most prominent in neutralizing alkali. While results vary with individual cows, the average amount of acidity of fresh milk is about 0.08 per ct., calculated as equivalent to lactic acid. If one desires to estimate more closely the amount of real lactic acid in milk, it is necessary only to subtract from the results commonly found .1 per ct.

Just how much deduction should be made in case of cream, it is more difficult to say. For ordinary work in creameries, such distinctions are not essential.

Therefore, in the results given in Table I, we have not stated the absolute amount of lactic acid present in the cream; but the results, in the form given, are more readily comparable with the results obtained in creamery work.

THE RELATION OF CALCIUM CASEIN, CASEIN AND CASEIN LACTATE TO THE PROTEIDS OF BUTTER AND BUTTERMILK.

The curd present in butter is casein lactate, when the amount of lactic acid formed in cream ripening exceeds 0.5 per ct. In butter made from cream ripened so as to contain less than 0.5 per ct. of acid, the same compound of casein is apt to be present ultimately in the butter, especially if buttermilk is left in the butter to any extent; because the milk-sugar, present in the buttermilk remaining in the butter, is changed in time to lactic acid, which acts upon any calcium casein or free casein in the butter, producing finally the compound usually present in butter made from well-ripened cream.

In butter made from sweet cream, we find in the butter essentially calcium casein with, perhaps, some free casein. With sufficient milk-sugar incorporated in such butter through the presence of buttermilk, we may have at different times any one, or a mixture, of the compounds of casein, as follows:—(1) calcium casein, (2) calcium casein and free casein, (3) casein and casein lactate, and (4) casein lactate. It is hardly probable that we should often find calcium casein alone in sweet-cream butter, as it is commonly made; though it would be possible to make the butter so that it would contain only calcium casein. In ordinary sweet-cream butter, when fresh, we commonly find a mixture of the two forms, calcium casein and free casein. Later, after the formation of more lactic acid, we may have free casein alone, which with increasing amounts of lactic acid will be gradually changed into casein lactate, the form commonly present in commercial butter made from ripened cream.

The amount of milk-albumin in normal butter is very minute under any conditions.

The curd of different butters and of the same butters at different ages presents quite different appearances. For special examination of its properties, the curd of butter is obtained by dissolving the fat in ether, or by melting the butter at as low a temperature as practicable and allowing the curd and brine to settle beneath the layer of butter-fat. The curd prepared from fresh butter, made from cream having an acidity of .5 or .6 per ct., is gelantinous in appearance and does not readily separate into small particles on standing. The curd of butter that is a few weeks old often appears granular. This is due, as we shall point out later, to the action of salt upon the physical properties of the casein lactate.

THE RELATIONS OF PROTEIDS OF BUTTER TO THE MOTTLING OF BUTTER.

The subject of mottled butter has attracted more or less attention and has been much discussed in dairy papers. However, the literature relating to actual investigations of mottled butter is very meagre. The only available work done in this country is described in Bulletin No. 64, Maryland Agricultral Experiment Station, by C. F. Doane, on "A Study of the Cause of Mottled Butter"; and in Bulletin No. 80 of the Iowa Agricultural Experiment Station, by G. L. McKay and C. Larsen, there is a brief treatment of "Gritty Salt as a Cause of Mottles." In order to ascertain the consensus of dairy authorities on this subject, the following inquiries were sent to the most prominent teachers of dairying in our county:

1. Does mottling of butter occur at one particular time of year more than another? If so, when? Why?
2. What different kinds of mottling do you recognize?
3. What do you regard as the causes that produce mottling?
4. Has ripening of cream anything to do with mottling? If so, how?
5. Does the temperature of churning influence mottling?
6. Does the temperature of the wash-water influence mottling?
7. Does the size of granules influence mottling?
8. Does salt influence mottling?
9. Has the butter color used anything to do with mottling?

10. Can you control effectively the mottling of butter? If so, how?

11. What is your theory in regard to the mottling of butter; that is, the causes producing it and the manner in which they produce it?

12. Are butter-makers in your section troubled with mottling, so far as your observation goes?

It is a matter of much interest to consider the replies received in answer to these questions.

1. *Does mottling of butter occur at one particular time of year more than another? If so, when? Why?*

In most cases it is reported that mottling occurs more frequently in cold weather, because it is more difficult to distribute the salt evenly through the butter, owing to the lower temperature of the wash-water and the greater firmness of the butter.

2. *What different kinds of mottling do you recognize?*

There is considerable variation in the replies made to this question. Summarizing all the different statements, the question is answered as follows: (1) An uneven distribution of color showing in small patches, (2) streaking or wavy mottles, (3) white specks, and (4) dapples. In most cases the expression indicates only one kind of mottling but varying in form and showing as streaks, waves or cloudiness.

3. *What do you regard as the cause of mottling?*

Every reply indicated the uneven distribution of salt in butter as the chief or sole cause of mottling. Additional or contributory causes are given as follows: (1) Uneven cream-ripening, (2) pasteurizing sour cream, (3) insufficient working, (4) chilled granules worked too soon.

4. *Has ripening of cream anything to do with mottling? If so, how?*

The general opinion is that cream-ripening has no relation to the mottling of butter, except that white specks in butter are often caused by over-ripe cream.

5. *Does the temperature of churning influence mottling?*

The general belief expressed is that churning has little or nothing to do with mottling. The following special suggestions are made: (1) Some temperature conditions of churning make

difficult the even distribution of salt and so contribute to mottling. (2) Too low or too high churning temperature may interfere with proper working of butter and consequent distribution of salt, thus favoring the formation of mottles. (3) If butter is made too hard the salt cannot be easily distributed uniformly. (4) Overripe cream churned at too high temperature produces mottles.

Summarizing these statements, it is the prevailing belief that the temperature of churning may affect the mottling of butter, when the uniform distribution of salt is made difficult, especially churning at low temperature.

6. *Does the temperature of the wash-water influence mottling?*

Some state that the temperature of the wash-water has no influence upon the mottling of butter. Several hold that the use of water so cold as to harden the butter considerably would cause mottling by preventing the uniform distribution of salt. One states that mottles are produced whenever the wash-water is colder than the butter. Another claims that mottles are unusual when the wash-water, salt and butter are of the same temperature.

7. *Does the size of granules influence mottling?*

The general belief expressed is that there is no relation between the size of butter-granules and mottling. One states that large granules, when hard, favor mottling; but, when the butter is soft, the size of granules makes no difference. Two state that small granules are preferable since large granules favor mottling.

8. *Does salt influence mottling?*

The expression is unanimous that the uneven distribution of salt is the chief, if not the sole, cause of mottling.

9. *Has the butter color used anything to do with mottling?*

All state that butter color properly used is not, in their experience, ever a cause of mottling.

10. *Can you effectively control the mottling of butter? If so, how?*

Summarized in the briefest expression, the belief of all is that mottles can be prevented by proper working of butter, that is, by effecting a complete and uniform distribution of salt through the mass of butter. Described in more detail, the even distribu-

tion of salt and the resulting control of mottles can be accomplished by churning between 52° and 55° F. to granules the size of wheat grains, drawing off buttermilk, washing once with water below 50° F., draining, salting and allowing to stand two to four hours before working.

11. *What is your theory in regard to the mottling of butter, that is, the causes producing it and the manner in which they produce it?*

All answers agree in assigning as the main cause of mottles in butter the uneven distribution of salt or brine as the result of insufficient or inefficient working. The manner of production is generally explained by the statement that salt or brine intensifies or deepens and so changes the color of butter, the light parts containing less salt or brine than the darker portions. One holds the belief that there is more moisture in those portions of butter containing more salt and this produces change of color.

12. *Are butter-makers in your section troubled with mottling, so far as your observation goes?*

There is more or less trouble but less than formerly, owing to the better education of buttermakers.

The general teaching of to-day about the mottling of butter is well summarized by Mr. H. Hayward in Circular No. 56 of the U. S. Department of Agriculture, Bureau of Animal Industry, entitled "Facts concerning the history, commerce, and manufacture of butter;" and we quote from this circular, pp. 185–6:— "One of the serious defects often found in butter is lack of uniformity of color, or what is commonly known as 'mottles.' This defect is seen in white streaks, spots or blotches, which are most pronounced when a lump of butter is cut so as to show a broad, smooth surface. If this cut surface is held at a proper angle to the light, any lack of uniformity in color will be plainly noticed. So serious is this defect considered that butter otherwise perfect, but mottled, is graded as second class in the large markets. The causes to which this fault can be attributed are, first, particles of curd, differing in size, incorporated in the butter, and, second, an uneven distribution of salt. Mottles in creamery butter are seldom caused by specks of curd, but in the poorer classes of dairy butter this kind of mottles is not infrequently seen. They are most likely to occur when the cream

from which the butter is made is thin and allowed to ripen without being stirred, or when it is over-ripened without being strained. The cream being churned under these conditions, lumps of coagulated cream are incorporated in the butter, and as the casein does not take the butter color the result is a product full of white specks. When the trouble is caused in this way it can be obviated by washing the butter twice in a weak brine after the buttermilk is thoroughly drained off. After the last washing, instead of draining the brine from the butter, as is usually done, the butter should be dipped out of the brine with a hair or wire sieve; the specks of curd, being heavier than butter or water, will have sunk to the bottom of the churn.

"Most of the mottles found in butter, however, are caused by an unequal distribution of salt. When the wash-water is considerably colder than the butter-granules the exterior of the latter become harder than the interior; this prevents an equal absorption of the salt when the butter is salted and worked, and mottles result. Also, when thin cream is churned at a low temperature the butter usually comes in round, shot-like granules; on account of being round and quite firm it is with difficulty that the salt is equally distributed and, unless great care is exercised, the finished butter is mottled. Of course, if under the most favorable conditions the butter is not worked enough to distribute the salt equally, mottles will be noticed in the finished product.

"Mottles may be prevented, then, by avoiding high temperatures in ripening cream, by frequent stirring during ripening, by straining the ripened cream into the churn, by avoiding exposure of the butter to temperatures too low while in granular form (which causes a difference between the interior and exterior of the butter-granules) and by working the butter sufficiently to cause an equal distribution of the salt."

It is very noticeable that in all the dairy literature which has come to our hand there is no suggestion that the proteids present in the cream have any connection with mottles in butter, except that single form which comes from curdled casein specks or particles; but this form is of so infrequent occurrence, compared with the other form, that many teachers do not apply the term mottles to the discoloration caused by curd particles. It is to the other form of mottles that we have given our attention,

that is, the form characterized by light-colored streaks, waves or large patches. It should be stated that Doane in the bulletin already referred to considered the relation of casein (casein lactate) to mottled butter but concluded that this proteid had no relation to the light-colored streaks of mottled butter.

Storch[1] appears to attribute the formation of motties to an excessively large number of minute liquid drops of what he calls "watery mucoid substance," the difference in the size and number of these liquid drops being caused by the action of special micro-organisms during the ripening of cream. This theory lacks satisfactory demonstration and has not been received with favor.

GENERAL METHOD USED IN MAKING BUTTER IN EXPERIMENTS.

Before giving the detailed results of our work, we will give an outline of the method employed in making the butter used in our experiments. In carrying on some of the practical details of this work, we are indebted for coöperation to Mr. Geo. A. Smith, Dairy Expert. The butter-making was carried on as follows, except when otherwise specified in individual experiments:—The cream was pasteurized and contained 28 to 30 per ct. of fat. A carefully prepared starter was used in ripening the cream, the degree of acidity being made to vary in different experiments, but in most cases amounting to 0.6 to 0.7 per cent. The temperature of churning was commonly at 50° to 55° F. The churning was stopped when the granules were about the size of grains of rice, except in those cases where the churning was purposely carried beyond this point. After the buttermilk was removed from the granules, they were treated twice with water at 40° to 45° F., being allowed to drain well after each washing. We were careful to keep the temperature of the granules down during the washing so that they would not adhere and form lumps but retain their individuality. The completeness of washing the granules can be effected by adding the water in the churn and giving the churn a few revolutions. For conditions of normal work we took pains to remove the buttermilk as completely as possible from the granules. The butter was then salted at the rate of one ounce of salt for one pound of butter, and worked at once in some cases or allowed in others to stand a varying length

[1]*The Analyst*, 22:206-7 (1897).

of time before working, from a few minutes to one or two hours, according to convenience.

RELATION OF RICHNESS OF CREAM TO MOTTLED BUTTER.

Cream was separated so as to contain 40 per ct. of fat, and from a portion of this we made cream containing 20 per ct. of fat by adding skim-milk The creams were handled under the same uniform conditions. The churning temperature was 50° to 52° F.; the granules were treated twice with wash-water at 45° F.; salt was added at the rate of one ounce to a pound of butter. When the butter-granules were about the size of grains of rice, there were no mottles in either case, but when the butter was over-churned and gathered in chunks, mottling took place. In the case of the rich cream, when over-churned, the butter was pasty and the mottles occurred in large patches, the whole mass of butter being rather light-colored from the presence from an excess of buttermilk. The richness of cream does not appear to have any influence in causing mottles in butter provided it is handled in a normal manner during the process of butter-making. More care needs to be exercised in churning rich cream to prevent over-churning than in case of cream poorer in fat.

RELATION OF RIPENESS OF CREAM TO MOTTLED BUTTER.

We churned creams having acidity of .22 and .25 per ct. and also some of the same creams ripened to acidity of .4 and .65 per ct. These were all churned at 55° F. and the granules washed twice with water at 40° F. The sweet cream was churned so as to come in fine granules and in lumps as large as hickory nuts or larger. The ripened cream was similarly treated. The butters were salted in the usual way. In each case, mottles were obtained in the butter in the case of the over-churned cream and no mottles in the butter made from granules of the usual size. In numerous other experiments, we have varied the acidity of the ripened cream from .38 to .78 per ct. and obtained butter without mottles except as the result of some condition other than that of the acidity of the cream used.

In one case, we added a starter to some sweet cream and churned at once, churning at 52° F. and washing the butter-granules twice with water at 45° F. Salt was added in the usual

amount. In one case, the granules were fine and produced butter without mottles, while in another case the granules were overchurned into lumps and mottled butter resulted.

The matter of white specks of curd in butter, as the result of over-ripened cream, we have not touched at all in our work, since all the facts in connection with this trouble have been well known for some years.

RELATION OF TEMPERATURE OF CHURNING TO MOTTLED BUTTER.

The temperature of churning was usually kept between 50° and 55° F. but variations were made in special experiments, ranging from 43° to 61° F. Churning at higher temperatures favors the production of mottles to some extent, since overchurning takes place more readily at higher temperatures and the butter-granules aggregate into larger masses more easily.

RELATION OF SIZE OF BUTTER-GRANULES TO MOTTLED BUTTER.

We controlled the operation of churning so as to produce butter-granules and aggregations of these varying in size. In our work we have designated the size of the granules as follows: Rice-grain size, pea-size (about a quarter inch in diameter), peanut size (about half an inch in diameter), hickory-nut size (about three-fourths inch in diameter) and walnut size (an inch or more in diameter).

In general, when the butter-granules were the size of rice grains at the close of churning, it was easy to make butter free from mottles by washing the granules twice with water at a temperature below 50 F°., preferably at 40 F°. But in several trials when the churning was made at 55° to 60° F. and the granules (rice-fine) were washed with water at 60° F., the butter was badly mottled since the granules adhered and formed lumps at that temperature before the washing could be completed. In several cases, we obtained very slight mottles when the temperature of the wash-water was 50° to 52° F., the granules being rice-fine.

When the granules of butter were about the size of peas, there was no difficulty in making unmottled butter, provided the temperature of the wash-water was kept down to 40° F. When the wash-water was at 52° F., we had traces of mottles. When the

butter granules were allowed to get as large as hickory nuts, mottled butter resulted in nearly every case, even when all other conditions were favorable to the production of unmottled butter. If, however, the buttermilk was once well removed, we found that aggregation of granules did not produce mottles. In several experiments we churned well-washed butter granules in water at a temperature of 60° F. and allowed them to aggregate into lumps the size of walnuts and no mottles were found in the finished butter as a result of this treatment.

It would, therefore, appear that any condition favoring the production of large aggregations of granules of butter *before removal of buttermilk,* such as overchurning, churning at higher temperatures, using wash-water at 60° or above, will favor mottling. In other words, failure to remove buttermilk from the butter-granules favors the production of mottles.

In this connection, it may be well to consider the manner in which buttermilk is retained in butter. We may for practical purposes regard buttermilk in butter as being present in two different relations. In the first relation the buttermilk is held enclosed in every individual granule of butter, and in the second relation it adheres mechanically to the outer surfaces of each granule. The buttermilk held within the minute granules can not readily be removed, while that adhering to the outer surfaces can be practically all removed by proper treatment of the granules with cold water. It is the buttermilk adhering to the outer surface of the small granules that we must consider in relation to mottles.

RELATION OF TEMPERATURE OF WASH-WATER TO MOTTLED BUTTER.

Best results were obtained by washing the butter granules with water at about 40° F. or even lower. Water at a temperature of 60° F. or above tends to make the granules adhere to one another and form larger masses, thus tending to prevent a sufficiently complete removal of buttermilk. It is important that the wash water be cold enough to keep the granules separate during the treatment with water.

RELATION OF WORKING BUTTER TO MOTTLED BUTTER.

When butter came in rice-fine granules and these were properly washed with cold water, working had no influence in producing

mottles. When the butter was overchurned, or allowed to form large aggregations before removal of buttermilk, mottles were present whether the butter was worked or not. In the case of the unworked butter, the mottled patches were much larger than in the worked. In one case, a badly-mottled butter was worked 12 times in an effort to remove the mottles. The result was simply to destroy the grain of the butter and reduce the mottles to a smaller size, distributing them more uniformly throughout the mass of butter but not removing them. In another case the granules were divided, one portion being worked only the usual amount, with mottles resulting. The other portion was worked several additional times, still preserving the grain, and the appearance of mottles was lessened, but the white portions were simply distributed more uniformly and the whole butter appeared lighter in color than normal.

RELATION OF SALT TO MOTTLES.

When the butter was not salted, there were no mottles, even when butter was overchurned and the granules were aggregated into lumps as large as walnuts; but in such cases the butter contained an excess of buttermilk and was much lighter in appearance than normal butter or than butter from the same cream would be when properly made and salted.

When the butter-granules were obtained in size of rice-grains and these were washed free from adhering buttermilk, mottles were not produced by the addition of salt even in very unequal proportions through the mass of butter. For example, some well-washed granules were placed in a butter-mold and then a layer of salt sprinkled on the layer of granules and then alternately layers of granules and salt. The cake of butter produced by this extreme treatment showed no mottles.

In one experiment, some unsalted butter, entirely free from any appearance of mottles, was cut into chunks and these were partly submerged in saturated salt solution for some hours. The portions of butter not covered by the brine were unchanged, while there was a very marked appearance of mottling on the surface of the submerged portion of butter. The appearance of mottles did not extend into the mass of butter but was confined to the surface in contact with the brine.

THE CAUSE OF MOTTLES IN BUTTER.

The fact that we have no mottles in butter when we have no salt has led to the belief that the salt is the sole cause of mottles and produces mottles as the result of its uneven distribution. It is held that the salt deepens the color of the butter-fat, the lighter portions containing little or no salt, the darker portions containing salt.

Effect of salt on color of butter-fat.—We desired to test experimentally the question whether salt brine has any influence on the color of butter-fat. We took some fresh, colored, unsalted butter, melted and filtered it, in order to separate the butter-fat from the other constituents of the butter. The filtered portion was allowed to harden and then cut into cubes and immersed in 30 per ct. brine in such a way that a part of the cube was in brine and a part out. There was not the slightest increase of depth of color or any other change in color noticeable.

In another experiment, some butter-fat was stirred with salt. The mixing produced a variegated color, not a true mottling, due to the grains of undissolved salt. The same effect is produced by mixing any white substance, sugar for instance, with butter-fat.

It would, therefore, appear that the mottling of butter is not produced by salt in the way generally held, viz., by affecting the color of the butter-fat itself.

Amount of salt in mottled and unmottled butter.—We took samples of butter by means of a trier, taking a plug through the ends of the prints examined. In one sample of unmottled butter, the amount of salt at opposite ends of a pound print was 3.65 and 2.61 per ct. In another unmottled butter, the salt varied from 4.6 to 5.3 per ct.; and in still another, from 1.86 to 2.59. In some badly mottled butter, the salt at different ends of some prints varied from 5.13 to 5.19 and 4.66 to 4.73, which showed very even distribution of salt. We may, then, have mottles where the salt is evenly distributed, and no mottles when the salt is unevenly distributed. Samples taken in the manner indicated by a trier give only the average of the mass but do not enable one to distinguish the amounts of salt in the lighter and darker portions separately.

Amount of salt in light and dark portions of butter.—It is a matter of common experience that the lighter portions of mottled

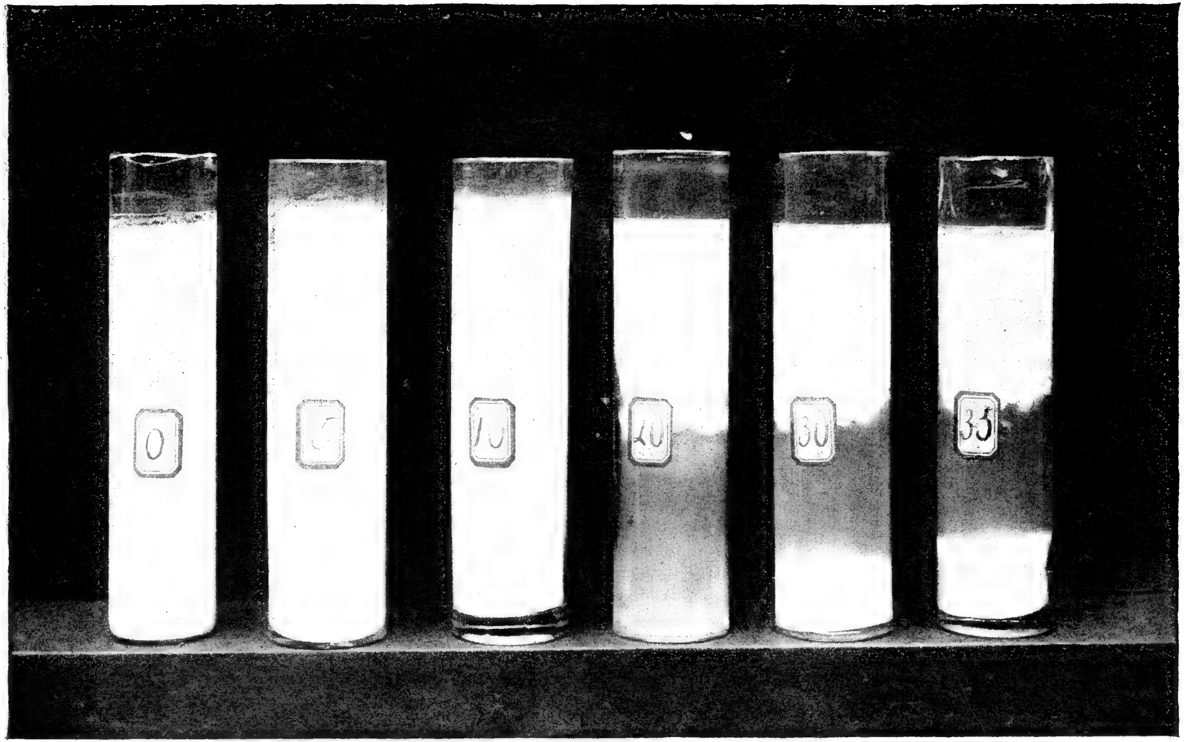

PLATE XXI.—ACTION OF SALT SOLUTIONS OF DIFFERENT STRENGTH ON THE PROTEIDS OF BUTTERMILK.

butter appear to the taste to contain less salt than the darker portions. We examined two samples of mottled butter, determining the amount of salt in the different colored portions when the butter was 24 hours old. The butter was somewhat overchurned purposely to produce conditions for mottling. The washing, salting and working were done in the usual way. The two butters gave the following results:

Butter 1 Light portion..................	0.91	per ct. of salt.
" 1 Dark "	5.45	" "
" 2 Light "	0.70	" "
" 2 Dark "	6.74	" "

These results agree with the sense of taste in showing that the lighter portions contain less salt than the darker portions of butter.

Distribution of brine in butter on standing.—In order to learn to what extent the salt of butter becomes more evenly distributed on standing, we determined at intervals the salt in the different colored parts of some butters referred to in the preceding paragraph. The results are as follows:

	24 hours.	48 hours.	5 days.	
Butter 1 Light portion.....	0.91	1.79	1.40	per ct salt.
" 1 Dark "	5.45	5.94	6.22	" "
" 2 Light "	0.70	1.69	1.69	" "
" 2 Dark "	6.74	6.04	6.22	" "

These results indicate that after 24 hours, the tendency of the salt to distribute itself more uniformly through the mass of butter is not very marked. The differences indicated may come mostly from variation in the samples examined.

The amount of proteid in mottled and unmottled portions of butter.—The amount of proteid was determined in mottled and unmottled portions of several butters and the results are as follows:

No. of experiment.	Per ct. proteid in light portion of butters.	Per ct. of proteid in dark portion of butters.
1	1.30	.76
2	.76	.14
3	.76	.36
4	.63	.25
5	.86	.31
Average.......	.86	.36

These results indicate that the light portions of butter contain more casein lactate than the deeper-colored portions. This casein lactate comes from retention of buttermilk. It is generally noticed that in working butter the liquid coming from the worker is turbid and milky when the buttermilk has not been removed, while it is more or less clear when the buttermilk has been properly washed out of the granules before salting and working.

The amount of water in mottled and unmottled butters.—The determination of water in mottled and unmottled butters gave the following results:

	Per cent of water in mottled butters.	Per cent of water in unmottled butters.
	13.03	12.87
	13.00	10.52
	11.97	10.50
	15.35	12.00
	15.50	13.30
Average....	13.77	11.84

The mottled butters vary greatly among themselves as well as the unmottled in respect to content of water. The larger amount of water in these mottled butters is the result of the retention of more buttermilk.

Properties of proteid in butter and buttermilk.—The chief proteid of butter made from ripened cream is casein lactate. In fresh, sweet-cream butter, the chief proteid is calcium casein (milk-casein) with more or less free casein. On standing, these constituents may change, forming more largely a mixture of free casein and casein lactate and, if milk-sugar is present to form sufficient acid, casein lactate entirely. The proteids of fresh buttermilk are the same as those contained in the butter, and the exact kind and amount depend upon the amount of acid formed. In ordinary buttermilk, in which the proteid is casein lactate, we notice that the proteid exists in fine particles in suspension. When buttermilk is treated with salt so as to form a brine about equal to that of normal butter, the salt causes the proteid to condense or concentrate in a more or less solid mass. This effect of salt is readily shown in the accompanying illustration. In the samples containing 20 per ct. or more of salt, the proteid has separated in a marked manner. This same action takes place

whether the proteid is calcium casein, casein or casein lactate. This action appears to be a purely physical one; the brine seems to harden the particles of proteid and cause the proteid mass to contract into less space in the tubes.

Relation of time to formation of mottles.—It is well known that the light-colored portions do not appear in butter at once after adding salt and working the butter, but several hours are required to develop them and the maximum development occurs in about 24 hours in our experience. In the experiments in which we treated buttermilk with salt, the separation or condensation of the proteid by the brine was not at its greatest until 24 hours had elapsed.

RELATION OF PROTEIDS OF BUTTER TO MOTTLES.

The facts presented in the foregoing pages appear to us to furnish a satisfactory explanation of the causes of mottles in butter. Reviewing these facts, we have seen that:

(1) Salt brine does not change in any way the color of butter-fat.

(2) The amount of salt may vary considerably in different portions of butter that is not mottled.

(3) In different portions of badly mottled butter, the distribution of salt may be very uniform throughout the mass of butter as a whole.

(4) In mottled butter, the light portions usually contain less salt than the darker portions.

(5) Mottles proper do not occur in unsalted butter.

(6) The amount of proteid in mottled butter is greater in the light portions than in the portions of normal color.

(7) Unsalted butter, containing buttermilk adhering to the outer surface of the granules, mottles on the surface when submerged in concentrated salt brine.

(8) Mottling does not occur in butter when the buttermilk, adhering to the outer surface of the small granules, is mostly removed.

(9) Small butter-granules (rice-size) washed with water at low temperature lose most of the adhering buttermilk and no mottles appear in the finished butter in the presence of salt.

(10) Large granules or chunks favor the retention and uneven distribution of buttermilk and we get mottles in the finished butter.

(11) Salt brine, as it usually occurs in butter, has the power of hardening, condensing and localizing in space the proteid (usually casein lactate) of butter. The action requires several hours.

From these facts, it would appear that mottles in butter are due primarily, to the presence and uneven distribution of buttermilk adhering to the outer surface of the small granules; and, secondarily, to the effect of salt brine upon the proteid of the buttermilk thus retained in butter. In the absence of either salt or excess of buttermilk, we have no mottling. Mottling ocurs most frequently as the result of an uneven distribution of buttermilk in the presence of salt distributed either evenly or unevenly. Mottling may be produced by an uneven distribution of salt in the presence of an excess of buttermilk even when uniformly distributed. In general, those conditions that favor the elimination of excess of buttermilk or its even distribution tend to prevent mottles; while those conditions that favor the retention and uneven distribution of buttermilk in butter tend to form mottles in the presence of salt.

THEORETICAL CONSIDERATIONS RELATING TO THE FORMATION OF MOTTLES IN BUTTER.

We have presented the facts showing that the formation of mottles in butter is due primarily to the presence and uneven distribution of an excess of buttermilk adhering to the outer surface of the small butter-granules, and, secondarily, to the action of salt brine upon the proteid of the buttermilk thus retained in butter. We desire to consider a little more fully how the action takes place.

A mass of butter must be regarded as an aggregation of butter-granules more or less loosely compacted. There is a variable amount of space between the granules and in these interstices we find the salt brine and also the buttermilk that is left adhering to the outer surface of the granules. There exist, therefore, more or less extensive channels through which movement of brine or buttermilk may take place to a limited extent, when conditions

favor any movement. The brine present in freshly packed butter does not necessarily remain, each particle, in the exact position in which it is left when packed and not subject to any further mechanical manipulation. The conditions that favor movement or limited circulation of the brine in butter are an unequal distribution of salt brine and buttermilk, producing a variation in the specific gravity which tends thus to become uniform within limited areas. When there is an imperfect removal of the buttermilk adhering to the outer surface of the small butter-granules, the buttermilk is unevenly distributed, being more or less localized in different portions of the mass of butter. When the salt brine comes into contact with these masses of buttermilk, the casein lactate is slowly acted upon by the brine, being hardened and remaining localized. The yellow or clear portions occur where the spaces between the butter-granules are filled with clear brine and are comparatively free from casein compounds. The fact that time is required to produce mottles is explained, first, by the time required for the movement or circulation of brine to take place and come in contact everywhere with the casein compounds, assuming that this has not occurred in the working of the butter, and second, by the amount of time required for brine to act upon the casein compounds of butter.

The discussion presented in the foregoing paragraph is, apart from the facts that have been clearly established, intended as a theoretical explanation or suggestion of what takes place when mottles form in butter. While the data presented point to the fact that there is some movement of brine in packed butter, the matter has not been studied in sufficient detail to justify any specific statement. Such a study is attended with serious difficulties, but we plan to make further investigation of this phase of the subject.

PREVENTION OF MOTTLES IN BUTTER.

Since the presence of mottles in butter is primarily due to an excess of buttermilk in the mass of butter-granules, the most effective method of preventing mottled butter is to free the butter-granules as completely as practicable from the buttermilk adhering to the small granules. In order to accomplish this, the churning should be stopped when the granules are about the

size of rice-grains, preferably at a temperature of 50° to 55° F. After the buttermilk has been drawn from the granules, they are treated with an amount of water at 35° to 45° F., about equal to the buttermilk drawn off, the churn being rotated a few times to insure complete contact, after which the water is drawn off and the granules are similarly treated a second time. The granules are then allowed to drain; the final drainage water from the granules should be clear. After this the salting and working are carried out in the usual way.

In working with large quantities of butter, it is obvious that somewhat more care will need to be used to make the washing effective than in the case of smaller amounts.

REPORT

OF THE

Department of Entomology.

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[1] Appointed August 5, 1905.

REPORT OF THE DEPARTMENT OF ENTOMOLOGY.

SULPHUR WASHES FOR ORCHARD TREATMENT, II.*

P. J. PARROTT, S. A. BEACH AND F. A. SIRRINE.

SUMMARY.

This bulletin contains the results of the second year's experiments to determine to what extent sulphur washes may be used in the place of bordeaux-arsenical mixtures for orchard treatment.

One application of a sulphur wash to apple trees reduced the scab by 22 per ct. A combined treatment, consisting of one application of a sulphur wash before blossoming and two applications of a bordeaux-arsenical mixture after blossoming reduced the scab 73.7 per ct., and wormy apples (codling moth injury) 27.1 per ct., which are practically identical with the results obtained by the usual three applications of the bordeaux-arsenical mixture for the control of these two pests.

In the experiments with pear trees an application of a sulphur wash before blossoming proved an efficient remedy for the pear blister mite (*Phytoptus pyri* Scheuten). Owing to the absence of pear scab in the orchards under observation no results were obtained as to the value of this treatment for this disease. For the same reason there were no data as to the effects of an early application of a sulphur wash upon brown rot.

The comparative tests of arsenite of soda and arsenate of lead for the treatment of the plum curculio gave inconclusive data, as this insect did no apprciable amount of injury. In the experiments with the codling month there was an average of 8.6 per ct.

* A reprint of Bulletin No. 262.

wormy apples upon the trees sprayed with arsenate of lead and 9.0 per ct. wormy apples upon the trees sprayed with arsenite of soda as compared with 20.7 per ct. wormy apples from the checks. The applications of the sulphur washes had no appreciable effect upon this insect.

INTRODUCTION.

The experiments upon the use of sulphur washes for orchard treatment were continued during the past season. The main object of this investigation is, briefly, to ascertain the range of these sprays as combined insecticides and fungicides and to determine to what extent they may be employed in place of the bordeaux-arsenical mixtures. Attention was directed to this problem by reason of the growing use of the sulphur washes for the San José scale, which in addition to being efficient remedies for this pest, have proven to be of more or less value for other insects and certain plant diseases common to fruit trees. The plan for the spraying of the orchards is essentially the same as that followed in the work of the previous year. The exceptions that may be noted are that comparative tests were made of the lime-sulphur wash and the lime-sulphur-caustic soda wash for scale treatment, and of arsenate of lead and arsenite of soda for the codling moth and the plum curculio.

OUTLINE OF THE EXPERIMENT.

PLAN.

Following the plan adopted last year, blocks of bearing apple, peach, pear and plum were divided into four sections, the varieties being distributed as evenly as possible. These sections were treated as follows: Section No. I, sprayed once with a sulphur wash; Section No. II, sprayed once with a sulphur wash before the opening of the buds and twice, after the dropping of the blossoms, with bordeaux mixture containing an arsenical poison; Section No. III, check, no treatment; Section No. IV, sprayed three times with a bordeaux-arsenical mixture,—once before the opening of the buds and twice after the dropping of the blossoms. Owing to the risk of injuring the foliage of the Japanese and native varieties of plums by the bordeaux-arsenical mixtures only

a few trees of these sorts were given the second and third treatments by this spray.

PREPARATION OF THE SPRAYS.

THE BORDEAUX-ARSENICAL MIXTURE.

Copper sulphate, pounds	5
Quicklime, pounds	$3\frac{1}{3}$ to 5
Water, gallons	50

The bordeaux mixture was made by the usual method. To each barrel of freshly prepared mixture either one pint of arsenite of soda or three pounds of arsenate of lead were added. These proportions were used for the treatment of all varieties under experiment.

THE LIME-SULPHUR WASH.

Lime, pounds	15
Sulphur, pounds	15
Water, gallons	50

This was prepared by first shaking the lime to a thin whitewash. The sulphur was then added and was stirred until it was thoroughly distributed throughout the lime; after which the mixture was boiled from one to two hours.

THE LIME-SULPHUR-CAUSTIC SODA WASH.

Lime, pounds	30
Sulphur, pounds	15
Caustic soda, pounds	6
Water, gallons	50

The sulphur was made into a paste with six gallons of water and was then poured over and well mixed with the lime. Water was used as needed to keep the lime-sulphur material during the slaking process in the consistency of a rather stiff paste. As soon as the lime was slaked the full amount of caustic soda was added and was stirred in the wash until the boiling had ceased.

In spraying the trees one application of the sulphur wash was made before the appearance of the leaves while the bordeaux-arsenical mixtures were applied as follows:—(1) Before the leaf buds burst; (2) just after the blossoms fell; and (3) from ten to fourteen days later than the second application, according to the plan of treatment as previously outlined.

LOCATION OF ORCHARDS.

The orchards in which the experiments were conducted are situated on Long Island, near Riverhead; in the lower Hudson Valley near Yorktown; and in western New York at Geneva in Ontario county, near Carlton Station in Orleans county, and at Youngstown in Niagara county. As the relative abundance of orchard diseases and insects is often determined by the local conditions the experiments were distributed over a larger area than before that data might be obtained on as many species as possible. In carrying out this work especial consideration was given to the forms which are susceptible to treatment during the dormant season or early spring.

The number of trees sprayed with the sulphur washes was 7325, divided as follows: Prunes 150, cherries 348, plums 1359, peaches 1149, pears 2822 and apples 1497. The details of the experiments giving the more important results are discussed under separate headings.

ORCHARD I. (SUFFOLK COUNTY.) PEACHES.

This orchard is adjacent to Centerville. For the experiment 164 Elberta and 25 Triumph peaches were selected for treatment. These trees have been given good care with respect to cultivation, pruning and fertilization. For the years 1899, 1900 and 1901 they received the regular treatment with bordeaux mixture for the prevention of leaf curl. In 1902 and 1903 spraying was neglected and the trees were severely injured by this disease. The San José scale was present in the orchard but the infestation was usually not extensive. For checks, 1300 trees in adjacent rows were reserved.

Conditions.—Applications of the sprays were made April 14, 15 and 16. During the two weeks immediately following the treatment rains fell on April 20, 25, 27, 28 and 29, the total precipitation for the period being 2.57 inches. The wash used was the self-boiled lime-sulphur-caustic soda wash.

Results on scale.—The sulphur wash proved very efficient. Several careful examinations made as late as October 1 failed to reveal any evidence of living scales.

Results on peach leaf curl.—With the exception of some of the leaves at the terminal buds the sprayed trees were practically

free from attacks of the leaf curl. A few leaves in various other parts showed small diseased areas, but the infestation was not sufficient to destroy the leaves or cause them to drop prematurely. The unsprayed trees were much defoliated by the curl and were in an unthrifty condition as a result of the attacks of this disease for three successive years.

Effect of sulphur sprays on trees.—A few Elbertas, which had made an advance growth at the time of spraying, showed a slight reduction in the amount of foliage. With this exception the appearance of the trees was normal. The setting of fruit upon the sprayed trees was 98 per ct. better than that of the unsprayed trees. But this difference largely disappeared with the June drop which resulted in an almost entire loss of the fruit upon all the trees in the various lots.

ORCHARD II. (SUFFOLK COUNTY.) PEARS.

This orchard is located about three miles from Riverhead, L. I. It consists of 130 Keiffer pear trees, which have been planted two years. These have been given careful cultivation but have not been sprayed until the present experiment was conducted.

Conditions.—On April 8, twenty of the trees were sprayed with the self-boiled lime-sulphur-caustic soda wash, the remainder being reserved as checks. The precipitation for the next two weeks was as follows: April 9, rain, 1.32 inches; April 11, rain, .115 inch; April 12, .285 inch; April 14, snow, .07 inch; April 16, rain, .12 inch; April 20, rain, .025 inch. The total precipitation for the period was 1.93 inches. One application of the wash was made which, on account of the small size of the trees, was very thorough.

Results on pear blister mite.—On April 8, the leaves of the unsprayed trees were nearly all infested with blister mite while the sulphur-treated trees were apparently unaffected. By May 16 there were a few leaves on four of the sprayed trees that showed slight traces of the mites, but the remaining sulphur-treated trees showed no evidence of infestation. About June 25 the mites upon the unsprayed trees were migrating to the newer foliage while none were observed upon the sprayed trees. A careful examination on August 1 showed that there were eight trees in the sprayed lot that had traces of mite work while the checks were uniformly well infested.

Results on pear trees.—The trees were uninjured by the treatment. The applications of the sulphur washes destroyed the lichens and left the bark clean. All foliage set after June 15 was still adhereing on October 20, while the unsprayed trees were nearly bare. All foliage set prior to June 15 on both the sprayed and unsprayed trees was very much affected by leaf rust (*Gymnosporangium* sp.). Duchess and Seckel pears in the same orchard were free from this disease and also from the blister mite.

Hand picking of infested leaves.—During the years 1903 and 1904 Mr. Sirrine conducted some experiments to determine the value of such treatment for the pear blister mite. During the last week in May, 1903, all infested leaves from five trees were removed and carried out of the orchard. One week later five more trees were treated in the same manner. An examination of these same trees on June 29 showed slight traces of infestation of the newly developed leaves. On May 16, 1904, these trees were carefully examined again when it was found that a number were abundantly infested. It is likely that the destruction of the infested leaves for two years in succession would have given more satisfactory results. At the best this method of fighting the mite is only practicable upon small trees and does not appear as effective as a thorough treatment during dormant season with a contact spray.

ORCHARD III. (WESTCHESTER COUNTY.) APPLES AND PLUMS.

This orchard is located near Yorktown. The apple trees vary from 30 to 50 years of age. These have for the past ten years received very careful attention with respect to the cultivation and spraying. The leading varieties are Baldwin, Gravenstein, Nonesuch and Roxbury. For the experiment 276 trees which were variously infested with scale were used. In the work with the plums 434 trees of the varieties Burbank, Lombard and Satsuma were selected for treatment. These were variously infested with scale but have been given the best of care.

Conditions.—Spraying with the sulphur washes was begun in this orchard on April 7 but owing to rains it was not completed until April 12. During every day that the trees were being treated the work was delayed by rains. On the evening of the 7th showers fell which continued at irregular intervals during the following days until the morning of the 12th when there was a heavy rain. The bordeaux-arsenical mixtures were applied April 18–20, June 2–6 and July 6–8. Owing to interference by

rain, it was impossible to follow the prearranged plan for spraying, and much difficulty was experienced in applying thorough treatments to the trees.

With the opening of the buds there were marked differences in the trees under the same treatment. This variation was shown in the color of the leaves and in the relative amounts of foliage and fruit, and was noticeable in all of the four sections. These results did not appear to be occasioned by this season's treatment but were apparently due to the ill effects of last year's spraying with bordeaux mixture. In the summer of 1903 applications of this mixture caused severe injuries to the foliage; and it is reasonable to suppose that the accompanying defoliation, probably coupled with injuries by the severe winter following, was largely responsible for the condition of these trees. With the picking of the fruit on September 27 the apples were carefully examined with respect to scale, codling moth and scab, the results being tabulated as follows:

TABLE I.—YIELD OF SOUND, WORMY AND DISEASED APPLES UNDER DIFFERENT TREATMENTS AT YORKTOWN.

NUMBER OF SECTION AND TREE	Yield of Picked Apples.							
	Sound.	Wormy.	Scaly.	Scabby.	Total.	Proportion of fruit.		
						Wormy.	Scaly.	Scabby.
Tree.	*No.*	*No.*	*No.*	*No.*	*No.*	*Per ct.*	*Per ct.*	*Per ct.*
SECTION I..........1	1096	400	113	312	1921	20.8	5.9	16.2
One application.. 2	1016	502	91	287	1896	26.5	4.8	15.1
of the lime-sul 3	1076	688	34	325	2123	32.4	1.6	15.3
phur-soda wash. 4	1666	994	76	472	3208	31.0	2.4	14.7
Av.						27.6	3.7	15.3
Tree.								
SECTION II....... 1	942	17	58	191	1208	1.4	4.8	15.8
One application 2	1378	47	248	128	1801	2.6	13.8	7.1
of the sulphur 3	889	26	44	195	1154	2.3	3.8	16.8
wash and two of 4	899	114	75	426	1514	7.5	5.0	28.1
bordeaux-arsenical mixture (arsenate of lead) Av.						3.6	6.9	16.9
Tree.								
SECTION III...... 1	286	400	178	183	1047	38.2	17.0	17.5
Check.......... 2	482	595	165	443	1685	35.3	9.8	26.3
No treatment. 3	1030	600	200	352	2182	27.5	9.2	16.1
4	2377	1104	1522	611	5614	19.7	27.1	10.9
5	969	363	160	181	1673	21.7	9.6	10.8
6	520	141	46	263	970	14.5	4.7	27.1
7	627	241	21	259	1148	21.0	1.8	22.6
8	1595	412	60	390	2457	16.8	2.4	15.9
Av.						24.3	10.2	18.4
Tree.								
SECTION IV. Three applications of 1	833	73	524	125	1555	4.7	33.7	8.0
the bordeau-ar- 2	505	36	11	24	576	6.2	1.9	4.2
senical mixture. 3	2004	98	522	144	2768	3.5	18.9	5.2
(arsenite of soda) 4	217	64	205	73	559	11.4	36.7	13.1
(arsenate of lead) 5	947	497	735	495	2674	18.6	27.5	18.5
Av.						8.9	23.7	9.8

Results on codling moth.—The average percentage of wormy apples (picked) from Section I is 27.6; Section II, 3.6; Section III, 24.3; and Section IV, 8.9. The sound fruit from trees treated with the bordeaux-arsenical mixtures averaged 93.8 as compared with 74.1 per ct. of sound fruit from the checks and from the trees treated with sulphur wash alone.

Results on scale.—The applications of the sulphur wash greatly reduced the numbers of the scale and insured the production of fruit which was practically free of scale. The average percentage of infested fruit from the sulphur-treated trees was 5.3 as compared with 17.0 per ct. of scaly fruit from the untreated trees. As in Orchard IV, the infested fruit of the unsprayed trees was usually much more conspicuously marked than that of the sprayed trees.

Results on plums.—With the exception of some trees of the varieties Burbank and Satsuma the scale was kept well in control by the sulphur sprays and clean fruit was harvested. The brown rot destroyed a few of the plums, but it was not sufficiently abundant to indicate the value of the sulphur washes for the treatment of it. Likewise the plum curculio caused very little injury, so that no data were obtained as to the comparative merits of the arsenite of soda and arsenate of lead for its control.

ORCHARD IV. (ONTARIO COUNTY.) APPLES.

This orchard is located in Geneva. It was planted about 25 years ago and consists of 42 trees of large size and of the varieties Baldwin and Greening. When the trees became infested is not known, but at the time of treatment the scale was well distributed over each tree, many of the branches being encrusted. A portion of this orchard was sprayed in 1902 with the lime-sulphur-salt wash, but with this exception the trees have been neglected. Last year's crop of fruit was practically worthless because of the scale.

Conditions.—The trees were sprayed April 9–12. The weather was cloudy with light winds. On the afternoon of the 9th a heavy thunderstorm occurred and intermittent showers fell during the remaining days. The buds were well swollen, but none of them had burst. The trees were given a thorough treatment with either the lime-sulphur-caustic soda wash or the boiled lime-sulphur wash, being sprayed from all directions until they were completely coated with the mixtures. On account of the lack of a suitable tower with the spraying machine, considerable diffi-

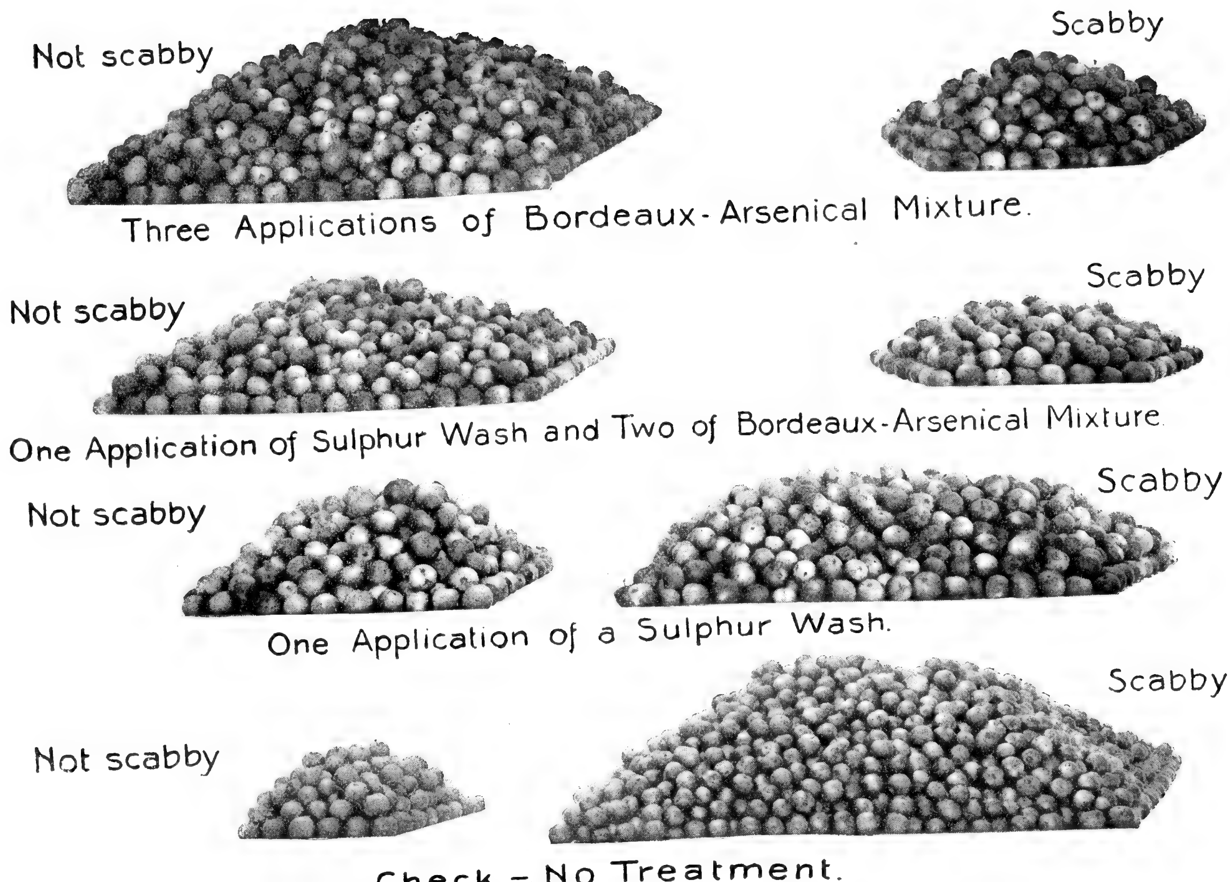

PLATE XXII.—EFFECT OF SPRAY TREATMENTS ON APPLE SCAB.

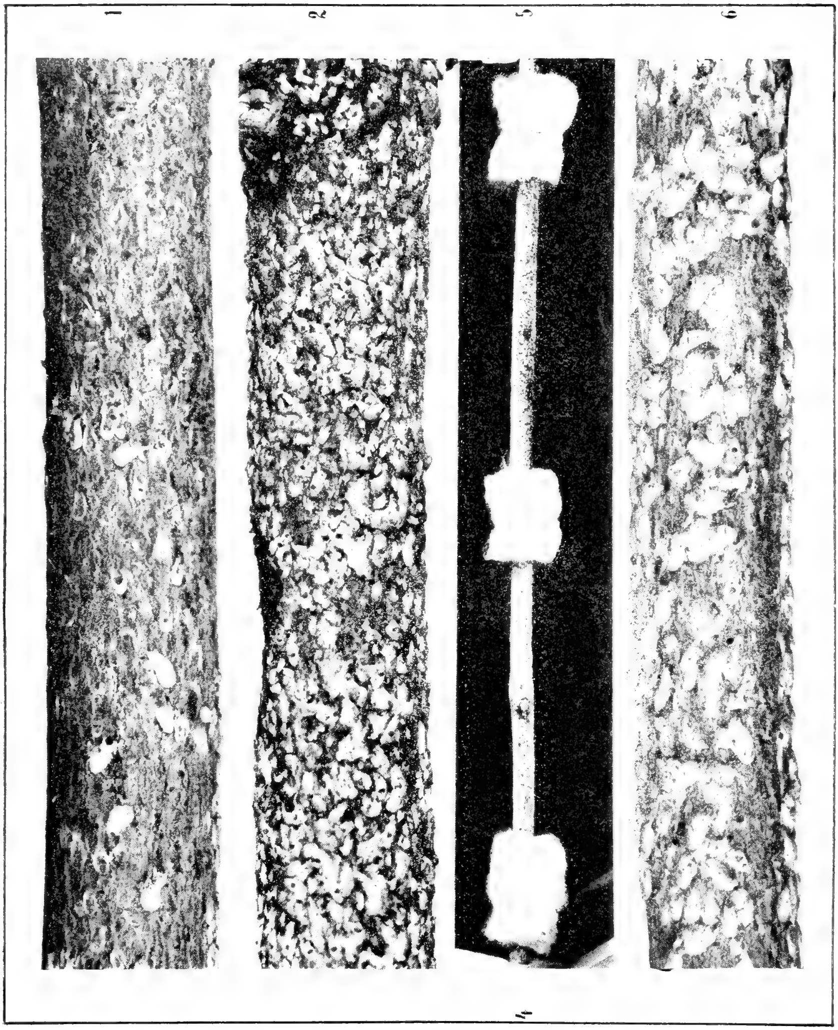

Plate XXIII.—Experiments with Dogwood Scurvy Bark Louse: 1, Enlarged View of 4; 2, Enlarged View of 5 Showing Increase of Young Scales; 4, Sprayed; 5, Check; 6, Condition of Scale Previous to Treatment.

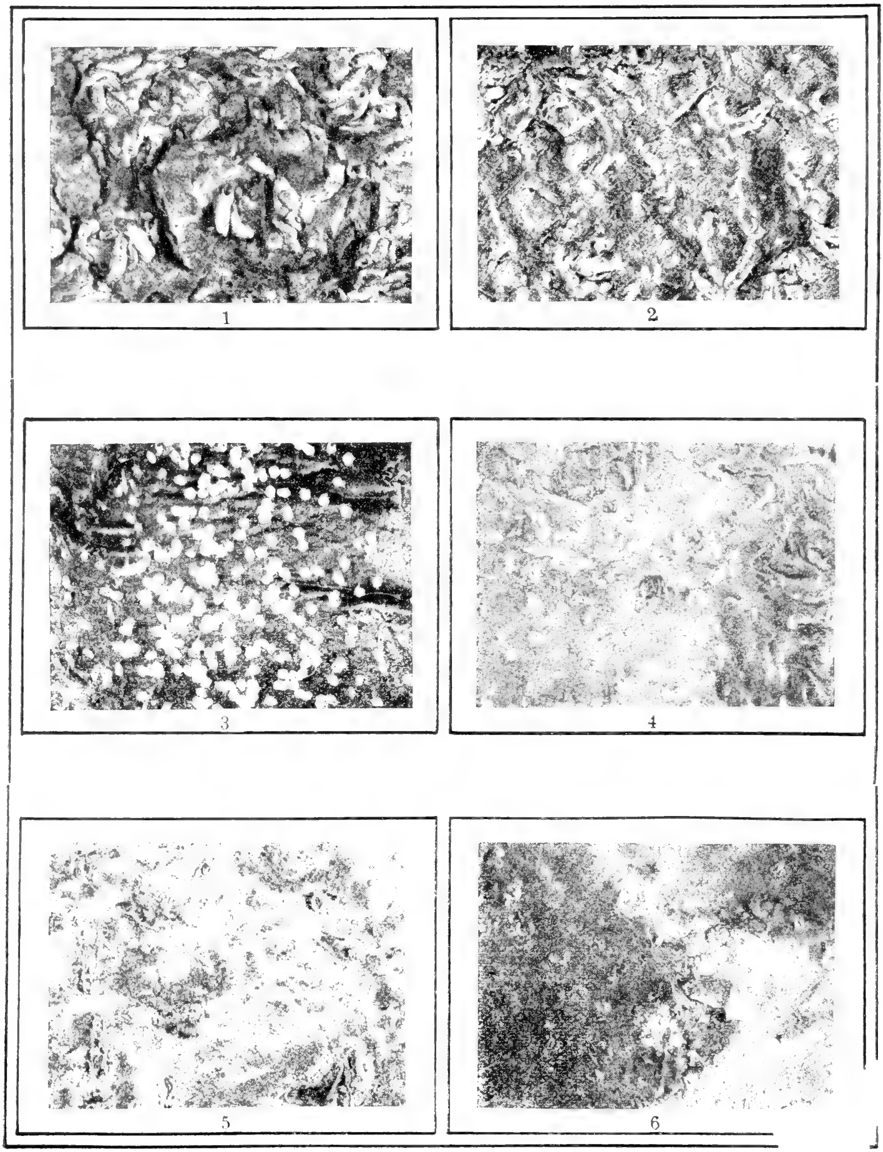

PLATE XXIV.—EXPERIMENTS WITH OYSTER SHELL BARK LOUSE: 1, 2
AREAS OF BARK FROM CHECKS; 4, 5 AND 6, AREAS FROM SPRAYED TRE

PLATE XXV.—SPRAYING OUTFIT AND [illegible] EMPLOYED IN ORCHARD VII, SECURING MOST SUCCESSFUL CONTROL OF SCALE.

culty was experienced in treating the upper portions of the trees. In attaining this end the lower branches were repeatedly drenched with the wash and were much oversprayed. The precipitation following the operations was as follows: April 13, 14 and 15, heavy snow during the afternoon and evening; April 19, heavy snow followed by rain; April 20, rain all day; April 24, light showers in the afternoon; April 27, rain in the afternoon and evening. The bordeaux-arsenical mixtures were applied April 12, June 1 and June 14. The second application with this spray was made just as the petals were dropping, for the purpose of controlling the codling moth.

Effects of sulphur sprays on trees.—On May 10, the buds were opened and the leaves were appearing in clusters. At this time it was evident that the treatment of the lower branches had reduced the number of buds, but it was hardly possible to determine the exact nature or the full extent of the injuries. By June 24 when the leaves and fruits were well developed the effects of the spraying were more plainly marked; for the lower portions of the sulphur-treated trees had relatively less foliage and fruit than like areas upon the untreated trees. The sprayed trees as a rule bore their crops on their topmost branches while with the unsprayed trees there was usually a more even distribution of the fruit. The sulphur-treated Baldwins had on the average much smaller yields than the untreated trees. The Greenings did not set as heavy a crop, and the yields of the sulphur-sprayed trees were on the whole not as large as those of the unsprayed trees. On October 16 the fruit was picked and counted. The yields are as follows:

TABLE II.—YIELDS OF SPRAYED AND UNSPRAYED TREES.

GREENINGS.				BALDWINS.			
SPRAYED.		NOT SPRAYED.		SPRAYED.		NOT SPRAYED.	
Tree.	Fruits.	Tree.	Fruits.	Tree.	Fruits.	Tree.	Fruits.
1	781	11	850	1	1293	10	3354
2	1604	12	5326	2	1199	11	3420
3	339	13	1032	3	2108	12	28[illegible]2
4	296	14	695	4	3035	13	3415
5	390	15	1383	5	3857	14	2491
6	406	16	496	6	1966	15	3183
7	372	17	925	7	1039	16	5708
8	1711			8	1760	17	2837
9	569			9	1310		
10	410						
	Av. 694		Av. 1529		Av. 1952		Av. 3404

The average yield of the sprayed Greenings was 694 apples and of the unsprayed trees, 1,529 apples. The average yield of the sprayed Baldwins was 1,952 apples as compared with 3,404 apples on the unsprayed trees. While recognizing the fact that there may be considerable variation in the amounts and regularity of fruit production for individual trees it is believed that a good portion of the differences noted between the sprayed and unsprayed trees is to be attributed to the effects of the sulphur sprays.

Effects of sprays upon apples.—As the crop from a tree was picked and examined it was piled on the ground to compare with yields of trees occupying similar positions in adjacent rows under different treatments. After the entire crop had been so arranged it was apparent, upon examination, that the apples from the sulphur-treated trees were on an average of better color and of a larger size than those from the trees which had not received such treatment. These results were especially marked upon the Baldwin apples but were not so conspicuous upon the Greenings; as the yields of this variety were, on the whole, small and the fruit, irrespective of treatment, was generally of good size and color. The superior coloration of the fruit of the sulphur-treated trees was to a large degree due to its freedom from scale and scab, but with the yields of a number of trees the hues of the fruit were also appreciably heightened and tended to become more brilliant. To ascertain the extent of the variation in the size of the apples by the different treatments the crops of four Greenings and eight Baldwins, representing all the lots, were graded carefully. In making the assortment, the apples were classified into three sizes. (1) Apples with a diameter of 2¼ inches or less; (2) with a diameter of more than 2¼ inches and less than 3 inches; and (3) with a diameter of 3 or more inches. The results are shown in the accompanying table:

TABLE III.—GRADES OF PICKED APPLES, BY SIZE, IN ORCHARD IV.

Tree.	Variety.	TREATMENT.	Size III.	Size II.	Size I.	Total.	Size III.	Size II.	Size I.
			No.	No.	No.	No.	Per ct.	Per ct.	Per ct.
1	Greening...	Check..............	4	928	209	1141	0.4	81.3	18.3
2	Greening...	3 Bordeaux - arsenical mixture.	132	673	33	838	15.8	80.3	3.9
3	Greening...	1 Sulphur + 2 bordeaux-arsenical mixture.	150	277	6	433	34.6	64.0	1.4

TABLE III.—GRADES OF PICKED APPLES, BY SIZE, IN ORCHARD IV.—(*Con.*)

Tree.	Variety.	TREATMENT.	Size III.	Size II.	Size I.	Total.	Size III.	Size II.	Size I.
			No.	*No.*	*No.*	*No.*	*Per ct.*	*Per ct.*	*Per ct.*
4	Greening ..	Sulphur wash.........	88	464	4	556	15.8	83.5	0.7
6	Baldwin...	Check................		772	228	1000		77.2	22.8
6	Baldwin...	3 Bordeaux - arsenical mixture.		748	252	1000		74.8	25.2
7	Baldwin...	1 Sulphur + 2 bordeaux-arsenical mixture.	157	837	6	1000	15.7	83.7	0.6
8	Baldwin...	Sulphur wash.........	51	900	49	1000	5.1	90.0	4.9
9	Baldwin...	Check................		612	388	1000		61.2	38.8
10	Baldwin...	3 Bordeaux - arsenical mixture.		692	308	1000		69.2	30.8
11	Baldwin...	1 Sulphur + 2 bordeaux-arsenical mixture.	216	771	13	1000	21.6	77.1	1.3
12	Baldwin...	Sulphur wash.........	11	907	82	1000	1.1	90.7	8.2

This year the apples of the two larger sizes were graded as first class and those of the smallest size as second class or culls. An estimate of the effects of the different treatments upon the size of the fruit may then be made by comparing the amounts of the second class fruit from each treatment. The sulphur-treated Greenings gave an average of 1.0 per ct. of this grade of fruit as compared with 11.1 per ct. from the untreated trees, making a difference of 10 per ct. better fruit in favor of the former. These figures show a greater difference in these respects than one would have imagined from a mere visual examination of the fruit and perhaps exceed a little the average difference for all the yields of this variety. The Baldwins sprayed with the sulphur washes yielded 3.7 per ct. second class apples as compared with 29.4 per ct. of the unsprayed trees, showing a difference of 25.7 per ct. better fruit in favor of the former. The results upon the Baldwins were not so surprising; for many of the trees not treated with the sulphur washes overbore and much of their fruit, independent of blemishes by scale, scab and codling moth, was condemned as culls because of its inferior size.

TABLE IV.—RESULTS OF SPRAYS UPON SCAB, CODLING MOTH AND SCALE ON GREENING APPLES IN ORCHARD IV.

No. of tree.	TREATMENT.	Yield. of apples.	Amount of Fruit.			Proportion of Fruit.		
			Scaly.	Scabby	Wormy.	Scaly.	Scabby	Wormy.
			No.	No.	No.	Per ct.	Per ct.	Per ct.
1	SECTION I. Sulphur wash....	784	63	422	287	8.0	53.8	36.6
2		1604	116	716	853	7.2	44.7	53.0
3		339	24	231	168	7.1	68.1	49.6
4	SECTION II. Sulphur wash + 2 bordeaux - arseni- mixture.	296	54	4	3	18.2	1.3	1.0
5		390	134	13	49	34.4	3.3	12.6
6		466	83	75	58	17.8	16.1	12.4
7		372	147	6	50	39.5	1.6	13.4
8		1711	953	107	229	55.5	6.2	13.3
9		569	464	4	44	81.6	0.7	7.7
10		410	354	1	35	86.3	0.2	8.5
11	SECTION III. Check	850	835	677	424	98.2	79.7	49.9
12		5326	4107	5239	2300	77.1	98.4	43.2
13		1032	549	360	480	53.2	34.9	46.5
14	SECTION IV. 3 Bordeaux-arsen- cal mixture.	695	551	35	71	80.1	5.0	10.2
15		1383	696	48	75	50.3	3.5	5.4
16		496	388	21	38	78.2	4.2	7.7
17		925	672	19	55	72.7	2.0	5.9

TABLE V.—RESULTS OF SPRAYS UPON SCAB AND CODLING MOTH ON BALDWIN APPLES IN ORCHARD IV.

No. of tree.	TREATMENT.	Yield of apples.	Amount of Fruit.		Proportion of Fruit.	
			Scabby.	Wormy.	Scabby.	Wormy.
			No.	No.	Per ct.	Per ct.
1	SECTION I. Sulphur wash........	1293	954	397	73.8	30.7
2		1199	878	461	73.2	38.7
3		2108	1018	1089	48.3	51.7
4		3035	2150	981	70.8	32.3
5	SECTION II. Sulphur wash+2 bordeaux-arsenical mixture........	3857	605	478	15.7	12.4
6		1966	372	252	18.9	12.8
7		1039	191	181	18.4	17.4
8		1760	301	281	17.1	16.0
9		1310	44	113	3.4	8.6
10	SECTION III. Check............	3354	3100	1057	92.4	31.5
11		3420	3306	1139	96.6	33.3
12		2822	2723	758	96.5	26.8
13		3415	3282	1107	96.0	32.5
14	SECTION IV. 3 Bordeaux-arseniical mixture....................	2491	488	154	19.1	6.1
15		3183	1181	146	37.1	4.6
16		5708	1404	281	24.6	4.9
17		2837	331	330	11.7	11.6

Results on codling moth.—At the picking of the fruit, commencing with October 16, the apples were sorted to ascertain the effects of the treatment upon this species. The average percentage of wormy apples, picked, from the Greenings in Section I is 46.4; in Section II, 9.8; in Section III, 46.5; and in Section IV, 7.3. The results upon the Baldwins are as follows: Section I, 38.3; Section II, 13.4; Section III, 31.0; and Section IV, 6.8. By the use of arsenical poisons in the second and third treat-

ments an average gain of 31.2 per ct. of sound fruit was made over the checks and trees treated with sulphur alone. It is obvious, that, in instituting a system of spraying for the treatment of apples, with the control of the San José scale by the sulphur washes as its central object, provision should be made for the usual applications of the arsenical sprays to prevent losses from the codling moth.

Results on San José scale.—As will be seen from the table the percentage of infested fruit upon the sulphur-treated trees is high. This was rather to be expected from an experiment conducted in the manner that this was. As provided for by the plans, nearly one-half of the number of trees, all well infested and comprising the central portion of the orchard, were left unsprayed. These it is likely, were a source of reinfestation to the adjoining trees, migration of the young lice being made possible by the wind and by the overlapping of the branches with the maturing of the fruit. Upon the Greenings 72.8 per ct. of the fruit on the trees not treated with sulphur washes was infested, as compared with 35.5 per ct. of the fruit upon the treated trees. There was also a marked difference in the relative amounts of the spotting of the fruit by the scale. The fruit of the unsprayed trees was to a large extent discolored by reddish blotches while much of that of the sprayed trees was barely blemished, but yet sufficiently marked to be classed as infested. All the fruit of the Baldwins, sprayed and unsprayed, was infested. The differences in the extent of infestation, noted with the sprayed and unsprayed Greenings, also held true with the Baldwins. The less satisfactory results upon this variety of fruit are in part attributable to the larger size of the trees, which undoubtedly prevented thorough spraying of the upper portions of the trees; and in part to the more extensive overlapping of the heavy-ladened branches with unsprayed trees in adjoining rows, which facilitated reinfestation.

Results on scab.—On June 24 the apple scab fungus was quite abundant upon the foliage of the check trees but its presence upon the sprayed trees was more difficult of detection. On July 8 the disease was for the first time recognized upon the fruit, but at this date there was no apparent variation in the amount of infection of the apples under different treatment. About

August 3 another examination was made when it was found that there was an increase in the quantity of diseased fruit which varied with the trees according to the treatment given, the checks having the greater amount and the trees sprayed with the bordeaux mixture the lesser amount of affected apples. With the picking of the fruit on October 16, the apples were sorted to determine the effects of the treatments with respect to this disease. The results in detail are given in Tables IV and V. The average results are as follows:

TABLE VI.—EFFECT OF SPRAYS UPON SCAB AND CODLING MOTH.

TREATMENT.	Scabby.	Wormy.
GREENING.	*Per ct.*	*Per ct.*
Check	71.0	46.5
3 Bordeaux-arsenical mixture	3.7	7.3
1 Sulphur wash and 2 bordeaux-arsenical mixture	4.2	9.8
1 Sulphur wash	55.5	46.4
BALDWIN.		
Check	95.3	31.0
3 Bordeaux-arsenical mixture	23.0	6.8
1 Sulphur wash and 2 bordeaux-arsenical mixture	14.7	13.4
1 Sulphur wash	66.5	38.3
AVERAGE.		
Check	83.1	
3 Bordeaux-arsenical mixture	13.3	
1 Sulphur wash and 2 bordeaux-arsenical mixture	9.4	
1 Sulphur wash	61.0	

In comparison with the checks the one application of the sulphur wash reduced the scab by 22 per ct.; the one application of the sulphur wash supplemented with the customary second and third treatments of the bordeaux-mixture reduced the scab by 73.7 per ct.; and the three applications of the bordeaux-arsenical mixture reduced the scab by 69.8 per ct.

The favorable results upon scab attending the applications of the sulphur washes may be partly attributable to the thinning of the fruit in the lower portions of the trees. For with these trees the larger part of the crop was produced upon the upper branches where the conditions with respect to shade, moisture and air circulation were less conducive to the development of scab. In none of the four other apple orchards under experiment was there any appreciable thinning of the fruit by the treatment with the sulphur washes. From these results it is believed that for the control of the scab an application of a sulphur wash before the opening of the buds may be substituted for the usual spray-

ing with bordeaux-mixture at this time for the prevention of this disease.

Results on apple aphis.—Small colonies of lice made their appearance in the opening leaf clusters of the sprayed and unsprayed trees, but the numbers were too small to indicate the relative effects of the different treatments. The rosy aphis was later much more abundant and was usually to be found upon the lower branches and towards the center of the tree. This species did very little injury and the amount of infestation showed no apparent variation with respect to the treatments.

ORCHARD V. (ONTARIO CO.) APPLES.

These are young trees and were top-grafted in 1895. The varieties represented are Jonathan, Ben Davis, Gano and Shackleford. The trees have received very careful attention in every respect. The applications of the bordeaux-arsenical mixtures were made to four hundred trees on May 10, June 2 and June 16. On October 4 the fruit was picked and the yields of a number of trees were sorted with respect to injuries by the codling moth, with the following results:

TABLE VII.—YIELD OF SOUND AND WORMY APPLES UNDER DIFFERENT TREATMENTS IN ORCHARD V.

VARIETY.	Number of section and tree. Treatment.	Yield of Picked Apples.				Yield of Windfalls.			
		Sound.	Wormy.	Total.	Per centage wormy.	Sound.	Wormy.	Total.	Per-centage wormy.
	SECTION IV.	No.	No.	No.	Per ct.	No.	No.	No.	Per ct.
Jonathan....	Block 1. Tree 1	270	63	333	18.9	118	41	159	25.8
	Arsenite of soda...2	400	93	493	18.9	181	91	272	33.5
	3	59	24	83	28.9	46	21	67	31.3
	Average.........	....	....	....	22.2	....	....	....	30.2
	Block 2. Tree 1	618	61	679	9.0	213	36	249	14.5
	2	439	51	490	10.4	159	45	204	21.6
	Arsenate of lead...3	838	97	935	10.4	296	47	343	13.7
	4	537	40	577	6.9	141	17	158	10.8
	5	147	17	164	10.4	51	10	61	16.4
	Average.........	....	....	....	9.5	....	....	....	15.4
	SECTION IV.								
Ben Davis...	Block 1. Tree 1	549	143	692	20.7	263	113	276	40.9
	2	237	45	282	16.0	64	39	103	37.9
	Arsenite of soda...3	130	27	157	17.2	111	25	136	18.4
	4	239	36	275	13.1	127	35	169	20.7
	5	257	38	295	12.9	147	73	220	33.2
	Average.........	....	....	....	15.9	....	....	....	30.2
	Block 2. Tree 1	317	44	361	12.2	107	12	119	10.1
	2	108	8	116	6.9	93	14	107	13.1
	Arsenate of lead...3	197	19	216	8.8	159	18	117	10.2
	4	520	38	558	6.6	168	16	184	8.7
	5	232	26	258	10.1	193	19	212	9.0
	Average.........	....	....	....	**8.9**	....	....	....	**10.2**

TABLE VII.—YIELD OF SOUND AND WORMY APPLES UNDER DIFFERENT TREATMENTS IN ORCHARD V.—(*Continued.*)

VARIETY.	Number of section and tree. Treatment.	Yield of Picked Apples.				Yield of Windfalls.			
		Sound.	Wormy.	Total.	Per centage wormy.	Sound.	Wormy.	Total.	Per centage wormy.
	Section IV.	*No.*	*No.*	*No.*	*Per ct.*	*No.*	*No.*	*No.*	*Per ct.*
Gano........	Block 1. Tree 1	203	58	261	22.2	93	40	133	30.1
	2	259	63	322	19.6	105	36	142	25.4
	Arsenite of soda...3	572	70	642	10.9	172	35	207	16.9
	4	330	58	388	14.9	307	74	384	19.3
	5	811	91	902	10.0	246	56	302	18.5
	Average........	....	....	....	15.5	....	....	....	22.0
	Block 2. Tree 1	89	16	105	15.2	311	60	371	16.2
	2	424	37	461	8.0	146	20	166	12.0
	Arsenate of lead...3	379	23	402	5.7	275	25	300	8.3
	4	366	50	416	12.0	215	20	235	8.5
	5	333	38	371	10.2	97	20	117	17.1
	Average........	....	....	....	10.2	....	....	.....	12.4
	SECTION IV.								
Shackleford..	Block 1. Tree 1	41	34	75	45.3	47	41	188	21.8
	2	88	44	132	33.3	126	72	198	36.4
	Arsenite of soda...3	125	44	169	26.0	34	10	44	22.7
	4	145	56	201	27.9	167	93	260	35.8
	5	267	75	342	21.9	257	76	333	22.8
	Average........	....	....	....	30.9	....	....	....	27.9
	Block 2. Tree 1	43	11	54	20.4	37	20	57	35.1
	2	65	13	78	16.4	63	29	92	31.5
	Arsenate of lead...3	107	20	127	15.7	390	72	462	15.6
	4	125	31	156	19.9	76	19	95	20.0
	5	252	44	296	14.9	229	27	256	10.5
	Average........	....	....	....	17.5	....	....	....	22.5

AVERAGE		
Arsenite of soda.............	21.1	27.6
Arsenate of lead..............	11.5	15.1

The trees sprayed with the arsenate of lead yielded 9.6 per ct. less wormy apples (picked) and 12.5 per ct. less wormy apples (windfalls) than those treated with the arsenite of soda.

ORCHARD VI. (ONTARIO CO.) APPLES.

These are young apple trees and have been for a number of years infested with the oyster-shell bark louse. Three of the worst infested trees were sprayed April 26 with the lime-sulphur-caustic soda wash to determine the effects of such treatment upon the scale. Besides the usual checks, comprising adjacent trees similarly infested, additional checks were reserved which consisted of untreated portions of the sprayed trees. Before applying the

washes, representative areas of the trees selected for treatment were first carefully wrapped with paraffin-paper, the outer edges being bound with bands of cotton and string to prevent any seepage by the liquids. After the applications of the sulphur washes were dry, the paper was removed, the cotton bands being retained. As a basis for estimating results, areas of bark having 180 to 200 old scales to the square inch were marked off with pins on the check and treated trees. On June 15 these areas were examined to determine the effects of the treatment upon the young scales. The results upon one treated tree and one untreated tree, both with smooth bark, are indicated by the accompanying table. The figures given show the number of young scales to each area respectively.

TABLE VIII.—CONDITIONS OF SCALES ON THE BARK OF SPRAYED AND UNSPRAYED TREES.

SPRAYED TREE.	COTTON BAND CHECKS ON SPRAYED TREE.	UNSPRAYED TREE.
Young scales.	Young scales.	Young scales.
No.	*No.*	*No.*
1	20	12
5	180	30
79 dead near cotton band	138 dead near cotton band	21
43 dead near cotton band	13 dead near cotton band	18
0	22	13
0	12	14
3	17	31
2	4	22
3	21	19
9	16	9
2	7	37
4	0	26

The results of a sulphur wash upon a much infested tree with rough bark are shown by the following comparison of the conditions of a sprayed and not sprayed tree with respect to the number of young scales settled upon areas of similar dimensions which, as before, consisted of representative sections of bark selected previous to the treatment. The date of the application of the wash and the time of the examination of the young scales are the same as with the preceding trees.

TABLE IX.—CONDITIONS OF SCALES ON THE BARK OF SPRAYED AND UNSPRAYED TREES.

SPRAYED TREE.	UNSPRAYED TREE.	SPRAYED TREE.	UNSPRAYED TREE.
Young scales under bark.	Young scales under bark.	Young scales unprotected by bark.	Young scales unprotected by bark.
No.	*No.*	*No.*	*No.*
6	38	1	5
4	14	2	18
4	40	4	10
3	28	4	22
4	31	3	17
4	26	2	18
17	32	2	28
13	9	7	13
12	3	6	30
9	17	4	6
6	21	3	4

On the tree with smooth bark there was, by the use of the sulphur washes, a reduction of 66.6 per ct. of the young scales as compared with the checks protected by the paper and cotton bands, or a reduction of 40.1 per ct. compared with the check tree. Upon the tree with rough bark the sulphur treatment affected a reduction of about 75.9 per ct. of the young scales.

MISCELLANEOUS EXPERIMENTS.

Results on scurfy bark louse.—During the work of the past two years opportunities have been given to note the effects of the sulphur washes upon this species. In several instances where the infestation was moderate, such treatment has usually checked the further development of the scales. When the incrustation has been heavy, the results attending the application of the washes have shown some variation in the amount of the reduction of the scales; but there has usually been a very appreciable destruction of the insects. In the work this season it was impossible to get data upon the normal effects of these sprays upon this species as the increase of the young scales upon the sprayed and unsprayed trees was so small that there were no apparent differences between the trees in this respect.

Results on dogwood scurfy bark louse.—On April 15 a number of bushes (*Cornus* sp.) infested with the bark louse (*Chionapis corni*) were sprayed with the lime-sulphur-caustic soda wash. Check plants and checks protected by paper and cotton bands were reserved as in the experiments with the oyster shell

bark louse. Plants having areas of bark containing about 160 to 180 old scales to the square inch were used. Portions of bark meeting these requirements were marked with pins. For the purpose of ascertaining the extent of the weathering of the scales several sections of infested wood had been obtained during the preceding November to serve as a basis to compare the conditions upon the selected plants with respect to the scale. On June 26 an examination of the plants was made. The results of the treatments as shown by four sections of bark, each one inch square, from each of the treated and untreated plants, are as follows:

TABLE X.—EFFECT OF SULPHUR WASH UPON DOGWOOD BARK LOUSE.

TREATMENT.	Scales June 26.	Reduction old scales.	Increase new scales.
	No.	*Per ct.*	*Per ct.*
Sulphur wash	371 old 0 young	50	0
Check (bands)	684 old 421 young	9	46.5
Check (plant)	598 old 988 young	20.7	110.3
Check—fall conditions—basis for comparison.	754 old		

Comparative tests of sulphur washes.—As announced in Bulletin 254 comparative tests of various sulphur washes were conducted this spring in the same manner as the fall experiments. Some interesting results were obtained by the different washes upon the trees and the scale, but as the work contributed only a little light upon the question of the best formula to employ, it is unnecessary to discuss the experiments in detail. For the present, preference is given to the boiled lime-sulphur wash, but where there are not the conveniences at hand for the preparation of the wash by external heat then the self-boiled lime-sulphur-caustic soda wash is advised.

ORCHARD VII. (ORLEANS CO.) APPLES.

This orchard is adjacent to Carlton Station and consists almost entirely of the variety Baldwin. The trees vary from 30 to 50 years of age and have been in the past somewhat neglected with respect to cultivation and treatment with spraying mixtures. In this experiment 56 trees were sprayed with the sulphur washes and 146 were divided evenly for the remaining treatments. The scale was well distributed throughout the orchard, and a

number of the trees which had not been previously treated for this pest showed considerable infestation upon some of their branches.

Conditions.—The trees were sprayed May 2-7. The weather during the application of the mixtures was fair. In many cases the buds had already burst, and in some instances the leaves were well out, while in others only the tips of the young leaves were beginning to appear. At this time the aphids were hatching and making their appearance in the leaf clusters.

Results on aphis.—On April 14 the trees selected for treatment and for the checks were examined to ascertain the relative numbers and the distribution of the eggs of the aphis upon them. Notwithstanding the abundance of this insect in the orchard during the preceding summer, very few eggs had apparently been deposited and it was only with careful searching that specimens were found. The extent of the infestation of the trees was apparently the same for both lots. On May 1 the young lice were making their appearance in rather surprising numbers at the tips of the opening buds. The condition of the trees at this time with respect to the aphids is shown by the following table which is based upon an examination of a number of buds chosen at random:

TABLE XI.—CONDITION OF APPLE BUDS WITH RESPECT TO APHIDS.

BUD NO.	Aphids to bud.	Bud No.	Aphids to bud.
	No.		*No.*
1	2	26	7
2	2	27	5
3	1	28	2
4	4	29	6
5	7	30	0
6	5	31	0
7	2	32	0
8	8	33	0
9	10	34	2
10	2	35	8
11	1	36	1
12	0	37	5
13	0	38	2
14	1	39	0
15	8	40	8
16	2	41	5
17	4	42	2
18	1	43	7
19	7	44	5
20	3	45	2
21	2	46	1
22	2	47	0
23	6	48	0
24	4	49	1
25	2	50	2

On May 2 the work of applying the sulphur washes commenced. Whenever the treatment was thorough a large percentage of the lice caught in migration upon the bark was killed, as were a goodly portion of those upon the partially opened buds. But when the lice were hidden in the pubescence of the more advanced leaves they were usually unharmed, as the leaves repelled the spray. The results of the sprays upon the aphid in the buds are shown in the following table:

TABLE XII.—CONDITION OF SPRAYED APPLE BUDS WITH RESPECT TO APHIDS.

BUD NO.	Aphids to bud.	Aphids alive.	Aphids dead.
	No.	*No.*	*No.*
1	2	2	0
2	2	1	1
3	1	0	1
4	1	1	0
5	2	1	1
6	5	1	4
7	1	0	1
8	2	1	1
9	1	0	1
10	1	1	0
11	1	1	0
12	2	0	2
13	4	0	4
14	1	0	1
15	3	2	1
16	2	0	2
17	2	2	0
18	2	2	0
19	9	7	2
20	5	5	0
21	5	3	2
22	1	1	0
23	1	1	0
24	1	0	1
25	1	0	1
26	1	1	0
27	6	6	0
28	5	2	3
29	2	1	1
30	3	0	3
31	1	0	1
32	4	3	1
33	6	4	2
34	1	1	0
35	1	1	0
36	8	8	0
37	1	0	1
38	2	0	2
39	5	1	4
40	1	0	1
41	1	0	1
42	4	2	2
43	5	1	4
44	5	4	1
45	5	5	0
46	5	2	3
47	1	0	1
48	7	2	5
49	2	0	2
50	3	0	3

The average percentage of aphids killed upon the buds is 45.5. The losses among the insects upon the bark were undoubtedly

higher than these figures. If the spraying had been timed two or three days earlier it is believed that the applications of the washes would have been much more effective upon the insects.

Results on scale.—The results obtained in this orchard were the most satisfactory of all the experiments. The applications of the sulphur washes checked the scale and for the most part preserved the fruit from blemishes by this insect.

Results on scab.—The amount of scab on the different plots showed such slight variation that no assortment of the fruit was made in this respect.

ORCHARD VIII. (NIAGARA CO.) APPLES AND PEARS.

This orchard is situated near Youngstown. It consists of 2036 pear trees principally Bartlett, Keiffer and Duchess, and 75 apple trees, principally of the varieties Baldwin and Rhode Island Greening. The pear trees vary in age from four to fourteen years and have received in every respect very careful attention. The scale has been present in the orchard three years and has been successfully controlled by whale-oil soap, crude petroleum and the sulphur washes. In 1903 the psylla was very abundant and caused quite extensive losses. The apple trees are about 30 years of age and are variously infested with the scale.

Conditions.—The trees were sprayed with the boiled lime-sulphur wash and the bordeaux-arsenical mixture April 18–26. The weather during this period was as follows: April 18, bright and clear; April 19, snow all day; April 20, snow all day; April 21, bright and warm; April 22, fair; April 23, fair; April 24, fair with rain in the afternoon. The later applications of the bordeaux-arsenical mixture were made June 2 and 16. In the application of the sulphur sprays much pains was taken to have the trees completely covered with the wash.

Results on pear psylla.—In the experiments with this species, 1876 trees were selected for treatment while four rows of 40 trees each, immediately adjacent on the west side, served as checks. The following excerpts from the field notes indicate the conditions of these trees throughout the summer with respect to this pest: April 14, adults were quite abundant under the loose bark and a few individuals were crawling about on last year's growth of wood. April 18–26, during the applications of the sulphur wash

adults were numerous and were usually resting on the buds and bark of the unsprayed trees and on the treated trees when the wash was well dried. April 30, adults were still very plentiful. May 30, adults were few in numbers; nymphs of the first, second and third stages were abundant upon the checks but were much less in evidence upon the sprayed trees. The axils of the fruit and leaf stems were beginning to be sticky with honey-dew and to have a sooty appearance. Ants were being attracted to the colonies of psyllas, being in greater numbers upon the unsprayed trees. An abundance of ants upon a tree usually indicated a check and was one of the most conspicuous signs of psylla infestation. On June 3, three and one-half rows of the untreated trees leaving 16 trees as checks, were sprayed with whale-oil soap to prevent the distribution of the psyllas throughout the orchard. June 27, eggs and nymphs of the first and second stages were abundant upon the checks and were to be found in greater numbers than before upon the trees treated with the lime-sulphur wash. The rows sprayed with whale-oil soap had fewer insects than the checks. The leaves of the checks generally and a number of the trees in other parts of the orchard were well spotted with globules of honey-dew. July 18, all stages of the pear psylla were represented, but the numbers of the insect, compared with former observations, were much reduced; a few of the originally much infested trees were covered with a blackish slime while the remainder showed little evidence of psylla attack aside from the dirty, sticky condition of the axils of the leaves and fruits. The checks were as a rule clean; a few trees were quite sticky because of the honey-dew and a number of others had the axils of the leaves and fruits discolored with the blackish honey-dew. September 14, the pears were being picked. The yield of the fruit was not appreciably affected by the psylla attack.

The pear psylla was not as numerous or as injurious as it had been during the preceding year. While abundant during the earlier part of the season this insect did not maintain its destructiveness throughout the summer. For this reason no opportunity was given to estimate the full effects of the sulphur wash for this pest. The work accomplished indicates that the thorough applications of this mixture afforded protection to the trees against the first brood of psyllas but that further investigation

is necessary to determine what effect this exemption would normally have upon the succeeding broods.

Results on codling moth.—Commencing with October 16, the apples were picked and sorted to determine the relative effects of the arsenite of soda and the arsenate of lead upon the codling moth. This examination was confined entirely to the Baldwins, twenty trees of which variety were selected from each of the two kinds of treatment. The results are as follows:

TABLE XIII.—YIELD OF SOUND AND WORMY APPLES UNDER DIFFERENT TREATMENTS AT YOUNGSTOWN.

NUMBER OF SECTION AND TREE TREATMENT.	YIELD OF PICKED APPLES.				YIELD OF WINDFALLS.			
	Sound.	Wormy.	Total.	Wormy.	Sound.	Wormy.	Total.	Wormy.
SECTION IV.	*No.*	*No.*	*No.*	*Per ct.*	*No.*	*No.*	*No.*	*Per ct.*
Tree 1	2630	42	2672	1.6	368	98	466	21.0
Arsenite of soda..... 2	3532	61	3593	1.7	350	110	460	23.9
3	4358	115	4473	2.6	502	119	621	19.2
4	4492	105	4597	2.3	583	108	691	15.6
5	3572	145	3742	3.9	256	35	291	12.0
6	6715	124	6839	1.8	468	45	513	8.8
7	3479	33	3512	0.9	266	44	310	14.2
8	3086	19	3105	0.6	145	21	166	12.7
9	5193	73	5266	1.4	420	59	479	12.3
10	4362	21	4383	0.5	225	75	300	25.0
11	2951	11	2962	0.4	293	45	338	13.3
12	3919	17	3936	0.4	236	44	280	15.7
13	5538	35	5573	0.6	260	62	322	19.3
14	5358	54	5412	1.0	661	81	742	10.9
15	2164	14	2178	0.6	136	17	154	11.0
16	2522	86	2608	3.3	203	52	255	20.4
17	3371	106	3477	3.0	458	170	528	32.2
18	2707	47	2754	1.7	498	144	642	22.4
19	2355	39	2394	1.6	400	107	507	21.1
20	3907	16	3923	0.4	1019	71	1090	6.5
Average.............	.....	.....	.....	1.5	.....	.....	.....	16.4
SECTION IV.								
Tree 1	3629	32	3661	0.9	1468	162	1630	9.9
Arsenate of lead..... 2	2480	10	2490	0.4	1600	30	1630	1.8
3	5121	34	5155	0.7	2790	210	3000	7.0
4	5280	30	5310	0.6	2173	62	2235	2.8
5	3900	13	3913	0.3	1080	65	1145	5.7
6	5111	22	5133	0.4	1115	50	1165	4.3
7	2351	20	2371	0.8	1000	23	1023	2.2
8	3857	18	2875	0.6	5719	66	5785	1.1
9	4424	18	4442	0.4	1630	39	1669	2.3
10	1382	8	1390	0.6	855	24	879	2.7
11	642	4	646	0.6	565	16	581	2.8
12	3913	19	3932	0.5	1952	139	2091	6.7
13	3837	14	3842	0.4	2538	40	2578	1.6
14	4834	10	4844	0.2	1705	20	1725	1.2
15	6196	34	6230	0.5	1304	51	1355	3.8
16	3589	10	3599	0.3	825	35	860	4.1
17	2687	.....	2687	0.	1250	12	1262	1.0
18	4042	14	4056	0.3	1612	23	1635	1.4
19	4112	31	4143	0.7	1836	217	2053	10.6
20	4249	15	4264	0.4	1495	140	1585	8.8
Average.............	.....	.....	.....	0.5	.....	.....	.....	4.0
SECTION III.								
Tree 1	2772	271	3043	8.9				
Check, no treatment...2	1108	106	1214	8.7				
3	1873	268	2141	12.5				
4	1695	193	1888	10.2				
Average.............	.....	.....	.....	10.0				

The average percentage of wormy apples (picked) from the trees sprayed with the arsenite of soda is 1.5, and from the trees

sprayed with arsenate of lead, 0.5, showing a difference of 1.0 per ct. more sound fruit by the use of arsenate of lead. With the fallen fruit the results of the two sprays are more marked; for there is 16.4 per ct. wormy fruit from the trees treated with arsenite of soda as compared with 4.0 per ct. from the arsenate of lead applications, showing a difference of 12 per ct. in favor of the latter poison. In comparison with the checks which had 10 per ct. of the fruit infested, there was, by using the arsenite of soda, 8.5 per ct. less wormy apples (picked) and by the arsenate of lead 9 5 less wormy apples (picked).

ORCHARD IX. (NIAGARA COUNTY.) PEARS.

This orchard is located on the lake road about three miles north of Lewiston. It consists of 119 ten-year old pears, principally of the varieties Bartlett and Kieffer. The orchard has been given careful cultivation and was in an excellent condition. In 1903 the trees were subject to a light attack by the pear psylla. The scale has been present in the orchard for a number of years, but has been well controlled by the sulphur washes for the past two years.

Conditions.—The trees were sprayed April 21. The weather conditions were the same as given for Orchard VIII. The checks for this experiment were 200 trees in an immediately adjoining orchard. As the work was solely for the purpose of determining the value of the sulphur washes for the pear psylla the treatment was entirely restricted to these sprays.

Results on pear psylla.—The psyllas were not numerous in these orchards at any time during the season. From April 30 to June 3 there were more psyllas upon the checks than the sprayed trees, but by July 18 these differences had disappeared and all the trees were quite free of the insects.

ORCHARD X. (NIAGARA COUNTY.) PEARS.

This orchard adjoins Youngstown. For the experiment 132 eight-year-old pears, largely Bartletts, were given treatment and a like number of the same varieties were reserved as checks. The trees had been much neglected and were as a rule well infested with the scale. Last year more or less injury was done in this orchard by the pear psylla.

The conditions governing the experiment and the results attending the use of the sulphur washes for the control of the pear psylla were substantially the same as those in Orchard IX.

DISCUSSION OF RESULTS AND CONCLUSIONS.

The experiments recorded in this bulletin represent the second year's work to ascertain to what extent the sulphur washes may be used in place of the bordeaux-arsenical mixtures for orchard treatment. In the investigations undertaken the utility of the washes has better been shown with the peaches than with other varieties of fruit; for when infestation with scale exists, one thorough spraying during the dormant season will control both scale and leaf curl, thus dispensing with the usual spraying with bordeaux mixture for the prevention of this disease. To ascertain if a similar or equally important substitution may be made for the spraying of other kinds of fruit has been the chief aim of the experiments discussed in detail in this bulletin. Owing to the absence of brown rot and pear scab no data have been obtained as to the value of the sulphur sprays for these diseases. In the work with pears one application of a sulphur wash proved an efficient remedy for the pear blister mite. In the experiments upon the apple, definite results have been secured, showing the value of sulphur sprays for apple scab. Upon the checks there was an average of 83.1 per ct. scabby fruit as compared with 61.0 per ct. scabby fruit from the trees treated with the sulphur wash alone, making a difference of 22 per ct. less scabby fruit for the sulphur-treated trees. The trees sprayed with a sulphur wash and with the two later applications of the bordeaux-arsenical mixture had 9.9 per ct. scabby fruit and 11.6 per ct. wormy fruit which correspond very closely with the results obtained with the three applications of the bordeaux-arsenical mixture upon these two pests.

By supplementing one application of a sulphur wash during the dormant season with the two later treatments of the bordeaux-arsenical mixture there was, in comparison with the trees sprayed with the sulphur wash, a reduction of 51.1 per ct. scabby fruit and 30.7 per ct. wormy fruit. From these results it seems evident that a plan of spraying well adapted for the

treatment of apple trees for scale, scab and codling moth is one application of a sulphur wash during dormant season, followed with the usual second and third applications of the bordeaux-arsenical mixture.

No opportunities have been afforded to test this system of spraying for the pear scab, but it is believed, that, as this disease is combated by the same remedies as the apple scab, the treatment outlined will control pear scab, scale, pear blister mite and the codling moth.

Some carefully conducted experiments with the boiled lime-sulphur wash and the self-boiled lime-sulphur-caustic soda wash have shown that both washes have efficiently controlled the scale. Preference is given to the boiled lime-sulphur wash as it is cheaper and when prepared by average orchardists is more likely to be uniformly effective. But if it is impossible to have suitable outfits for the preparation of a wash by external heat then the self-boiled lime-sulphur-caustic soda wash is advised. Either of these washes, properly prepared and thoroughly applied, may be relied on to control the scale on peaches and plums, and on pears and apples of moderate size. The pressing problem in this State to-day is to control the scale upon large apple trees in as easy and satisfactory manner. This has been accomplished where moderate infestation has existed, but large apple trees, that have been neglected and are well encrusted with the scale, which is hidden in deep cracks in the bark or is protected by close clinging bark, are not easily restored to a satisfactory condition. Trees in this state should be judiciously headed in and their rough bark removed as far as is practicable before the applications are made. Two sprays are commonly recommended for the treatment of such trees, which are crude petroleum and sulphur wash. As many orchardists are unable to apply oil safely and as apple trees may be drenched with the sulphur washes without causing any injury aside from the loss of some of the fruit and leaf buds, the sulphur sprays are advised. Experience in spraying trees in this badly infested condition suggests the wisdom of fruitgrowers keeping a sharp watch for the first appearance of the scale and of thoroughly spraying the trees thereafter as often as is necessary to keep the scale in control.

The general results of the comparative tests of arsenite of soda and arsenate of lead are as follows:

ORCHARD.	Trees sprayed.	Trees used in count.	WORMY APPLES.		
			Arsenite of soda.	Arsenate of lead.	Check.
	No.	*No.*	*Per ct.*	*Per ct.*	*Per ct.*
1—Yorktown	276	21	6.4	11.1	24.3
2—Geneva	400	38	21.1	11.5	....
3—Geneva	42	34	7.0	11.3	37.7
4—Youngstown	75	40	1.5	0.5	10.0
Average	....	....	9.0	8.6	20.7

The average percentage of wormy apples for the four experiments from the trees treated with arsenite of soda is 9.0 and from the trees treated with arsenate of lead, 8.6, showing a gain in sound fruit by the arsenate of lead of .4 per ct. In comparison with the checks there was a reduction of 11.7 per ct. wormy fruit by the arsenite of soda and 12.1 per ct. by the arsenate of lead.

ACKNOWLEDGMENTS.

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SPRAYING FOR THE SAN JOSE SCALE.*

H. E. HODGKISS, F. A. SIRRINE AND E. L. BAKER.

SUMMARY.

This bulletin contains the results of the past year's experiments to determine the effects of a number of spray mixtures upon the San Jose scale and fruit trees. In this work various sulphur washes, the kerosene-lime mixture and soluble oil sprays have been used. Applications of these have been made at intervals during the early spring, summer and fall.

The fall applications of the sulphur washes gave, on the whole, satisfactory results. In several instances peaches and plums sustained more or less injury. The treatment upon San Jose scale was generally effective.

The kerosene-lime mixtures have proven rather unsatisfactory, for the applications often gave variable results upon the scale and the trees. Comparative tests with several grades of lime indicated that Limoid made the more stable emulsion. Analysis of several preparations of the kerosene-lime mixture showed that the larger percentage of the oil did not settle with the lime but rose to the surface in an emulsion with the lime. The variable results upon trees and scale were due to the imperfect distribution of this emulsified portion in the mixture.

Some tests were made with a soluble oil spray known as Scalecide. Although this gave some satisfactory results on scale, further experiments are necessary to determine its merits for the treatment of commercial orchards.

INTRODUCTION.

The experiments upon the use of various spraying mixtures for the treatment of orchards were continued during the past year. The object of the investigations was to determine the effect of these sprays on the San Jose scale and on fruit trees. Past ex-

*A reprint of Bulletin No. 273.

perience[1] has demonstrated conclusively that the scale may be controlled by thorough applications of any of the recognized remedies, but in the work that has been accomplished there were evidences of losses in the fruit yields which were largely attributable to injuries received in the treatment. For this reason it was important that the work be continued in order to determine especially the probable effects of such practice upon fruit production in average years. Various sulphur washes, the kerosene-lime mixture and soluble oil sprays were used in this work. The results attending the application of each of these washes are discussed separately.

[1]N. Y. Agl. Exp. Sta. Bul. 254.
Ohio Agl. Exp. Sta. Bul. 144.
Ann. Rpt. Ohio State Hort. Soc., 63: 51. 1903

FALL SPRAYING WITH SULPHUR WASHES.

H. E. Hodgkiss and F. A. Sirrine.

Following the general plan outlined for former experiments, blocks of bearing apple, peach, and plum trees were selected in orchards situated in Ontario Co., near Geneva, and in Suffolk Co., near Northville. The conditions governing the treated trees were similar to those of last year with the exceptions of two orchards which received special treatment. Since differences in condition have an important bearing on the results, a brief description of each orchard is given.

Orchard I. (*T. C. Maxwell & Bros., Geneva.*)—The trees selected for treatment were seventy-three Reine Claude plums and twenty-five Fitzgerald peaches. The orhard has received very careful attention, and at the time of spraying was thrifty and entirely free from scale. Both varieties were about nine years old and had not been previously fall-sprayed.

Orchard II. (*H. H. Loomis, Geneva.*)—This is kept in clean cultivation but otherwise has received no care or previous treatment for insects. The trees are about twelve years old, and, with the exception of a slight infestation by the oyster-shell bark-louse, are thrifty and free from scale.

Orchard III. (*Thos. Maney, Geneva.*)—For the experiment, 129 Burbank and Reine Claude plums which had shown more or less scale injury during the previous year were selected. Both varieties are about seven years old and have received good care, particularly in the treatment of insects and plant diseases. This orchard was treated for scale in 1903.

Orchard IV. (*T. W. & J. P. Rice, Geneva.*)—A portion of this orchard comprising 102 Reine Claude and Burbank plums was used for a comparative test of the self-boiled lime-sulphur wash and various modifications of the kerosene-lime mixtures. The trees were about eight years old, vigorous, and with the exception of three trees were not seriously infested with the scale. No previous treatment for insect pests had been made in this orchard.

Orchard V. (*Israel Luce, F. A. Sirrine, Northville.*)—Peach and apple trees were used in this experiment. The peaches were selected with reference to vigorous growth and general neglect. The apples were young and healthy. Scale and leaf curl were present in the orchard during the previous year. The number of trees under experiment was 231, of standard varieties.

All orchards.—The total number of trees under treatment was 596; of these 41 were apples, 304 plums, 251 peaches. Checks were reserved in each orchard, which were representative of the sprayed trees.

CONDITIONS.

At Geneva the washes were applied between Nov. 11 and 22. The weather for this period was variable, generally cloudy with light winds. The temperature varied from 20° to 40° F. in the morning, and from 34° to 58° F. in the afternoon. There was no precipitation until Nov. 20, when a few snow flurries were followed by clear weather with a light snow at night.

During the treatment at Northville, made between Nov. 16 and Dec. 1, the weather was clear with brisk northeast to northwest winds.

The trees were sprayed once carefully and the following day any limbs not thoroughly coated received a second treatment. The weather conditions were much more favorable than in 1903, as severe cold did not set in until after the work was completed.

In each orchard, except Orchard IV, comparative tests were made with the several washes. In Orchard IV, the self-boiled lime-sulphur-caustic soda wash only was used in comparison with kerosene-lime mixtures.

PREPARATION OF THE WASHES.

The washes were the same as those employed during the previous year, viz.: The lime-sulphur-salt wash prepared with and without external heat; the lime-sulphur wash; and the lime-sulphur-caustic soda wash, prepared with and without external heat. The formulæ and methods of preparation are as follows:

BOILED LIME-SULPHUR-SALT WASH.

Lime	20 pounds.
Sulphur	15 "
Salt	15 "
Water	50 gallons.

This was prepared in the usual method by first slaking the lime to a thin whitewash, and then adding the sulphur and the salt. These ingredients were distributed thoroughly in the whitewash and the mixture boiled from one to two hours.

SELF-BOILED LIME-SULPHUR-SALT WASH.

Lime	40 pounds.
Sulphur	20 "
Salt	15 "
Water	60 gallons.

This wash was cooked without the direct use of external heat. First, the sulphur was made into a paste with hot water and was then emptied into a barrel containing forty pounds of lime, which was started to slake with twelve gallons of boiling water. During the slaking process, the barrel was covered to prevent the loss of heat. Occasionally the wash was stirred to secure a more uniform distribution of the sulphur in the whitewash. In twenty minutes after the time that the lime first commenced to slake, enough boiling water was added to make the required sixty gallons of mixture; after which the salt was added and stirred until dissolved. The wash was then strained and applied hot.

LIME-SULPHUR WASH.

Lime	20 pounds.
Sulphur	15 "
Water	50 gallons.

This mixture was made in the same manner as the boiled lime-sulphur-salt wash except that the salt was omitted.

SELF-BOILED LIME-SULPHUR-CAUSTIC SODA WASH.

Lime	30 pounds.
Sulphur	15 "
Caustic soda	6 "
Water	50 gallons.

In preparing this wash the lime was started to slake with six gallons of water; and, as soon as the slaking commenced the sulphur, which had just previously been made into a thin paste with hot water, was added and thoroughly mixed in with the slaking lime. To prolong the boiling of the wash, the caustic

soda was then used, with water as needed, and the whole mixture was kept thoroughly stirred. As soon as the chemical action had ceased the required amount of water was added, when the mixture was ready for use. The soda used in the preparation of this wash is a powdered 74 per ct. caustic soda, sold by the Penn Chemical Works, 1322 Washington Avenue, Philadelphia, Pa. It sells for 4 cents a pound and is contained in 50 lb. cans.

BOILED LIME-SULPHUR-CAUSTIC SODA WASH.

Lime.	30 pounds.
Sulphur.	15 "
Caustic soda.	6 "
Water.	50 gallons.

This was prepared in the same manner as the self-boiled lime-sulphur-caustic soda wash, after which the mixture was boiled for one or two hours over a fire.

RESULTS.

Orchard I: Peaches.—In the early spring with the opening of the buds the blossoms and leaves appeared normal and no difference could be seen between the check and treated trees. Subsequent examinations, made on May 22, June 14 and July 24, showed no apparent variation. On August 15 the foliage of the treated trees appeared better than that of the unsprayed trees. With respect to the fruit yields there was no difference. In every case the fruit was small and of poor quality.

Plums.—Buds on the check trees opened May 9, while those on the sprayed plums were retarded for nearly a week. At this time the untreated trees had uniformly more foliage, but observations made on May 12, 22, June 14 and July 24 showed very little difference in this respect. On Aug. 15 the checks had begun to drop the foliage owing to the attacks of the shot-hole fungus (*Cylindrosporium padi* Karst.) but this defoliation did not affect the fruit yield, which was very satisfactory in quantity and quality.

Orchard II: Apples.—A variation in the action of the washes was noticeable when the blossoms appeared which was apparent on some trees in all the rows receiving treatment. With the advancement of summer there was a more abundant growth on the sprayed trees, which appeared to be more vigorous than the checks.

Orchard III: Plums.—In the early spring the trees treated with the self-boiled lime-sulphur-salt wash showed more injury than the trees sprayed with the other washes. On some of the trees there was a destruction of nearly one-half of the leaf-buds. The remainder of the plums showed fewer leaves on the lower and inner spurs than the checks. However, the increased growth of the new wood caused a great improvement in the appearance of the sprayed trees which subsequently fully equalled the checks in quantity of foliage and fruit yields. The previous yield of plums was practically worthless from scale injury, but this year a clean crop was marketed.

Orchard IV: Plums.—The self-boiled caustic soda wash caused severe injury to a tree which was evidently weakened by scale in the previous year. Otherwise the condition of the sprayed trees was satisfactory and remained so throughout the summer.

It is well to mention that applications of the kerosene-lime washes in this orchard gave varying results and in some instances caused very severe injuries. A number of trees were killed and the remainder were so injured that they produced only about one-quarter of a crop of fruit. The trees treated with the sulphur wash yielded a full crop of fruit and on Aug. 15 were in much better condition than those treated with other sprays.

Orchard V: Peaches.—Early in the spring a comparison of sprayed and unsprayed peaches showed no apparent differences with respect to fruit and leaf buds. The varieties treated with the self-boiled caustic soda wash were the more exposed to the severe winds and on March 27 Mr. Sirrine reported a considerable shriveling of the young wood. Checks under similar exposure were less severely injured, while the trees receiving an application of the boiled sulphur wash were somewhat less exposed and consequently the injuries from this source were not as conspicuous. An examination on May 6 showed that 75 per ct. of the spurs on all the trees were killed, and it was evident from the condition of the checks that less than 10 per ct. of the injury on the treated trees was due to the spraying.

Effect on curl.—Peach leaf curl was present on both sprayed and unsprayed trees. The sprayed section had 1.5 per ct. of curled leaves as compared with 85 per ct. of curl on the checks.

Apples.—Applications of the self-boiled caustic soda wash had no injurious effect on the trees. This treatment practically eradicated the scale, only a few being found on fruit taken from isolated branches which apparently had not been covered by the spray. The apples on the checks were worthless from scale infestation.

SUMMARY.

The results from spraying in the autumn of 1904 have been quite satisfactory. In Orchard I there has not been at any time during the summer any evidence that the treatment was other than beneficial. A similar effect was seen in Orchard II. One section of Orchard III was somewhat severely injured by the application of the self-boiled lime-sulphur-salt wash, but this difference was overcome during the summer by the increased growth of the trees. The results from Orchard IV showed that the kerosene-lime mixtures were unstable and in many cases were unsafe washes; for the application often caused marked reductions in leaf and fruit buds, and in some cases the death of the trees. The lime-sulphur-caustic soda wash used in this experiment caused serious injury to one tree very badly infested with scale but otherwise the spray gave satisfactory results. The peaches in Orchard V were badly winter killed, but it is believed that about 10 per ct. of the buds were injured by the treatment. Apples in this same orchard were uninjured by the sprays, and the scale was satisfactorily controlled.

GENERAL SUMMARY AND CONCLUSIONS.

In the previous work upon this problem the results attending the application of the sulphur washes were somewhat conflicting, since some of the treatments caused serious injuries to the buds and blossoms, while others in no manner affected the health of the trees. But as regards the insecticidal value of the treatments all the experiments showed that applications at this season were uniformly effective upon scale. The work indicated that the injuries sustained by the trees were balanced by their increased vigor and fruitfulness due to the control of the scale. The probable losses that an orchard would sustain were not indicated by this single experiment. These, in order to be thoroughly understood, called for further observations covering a number of years.

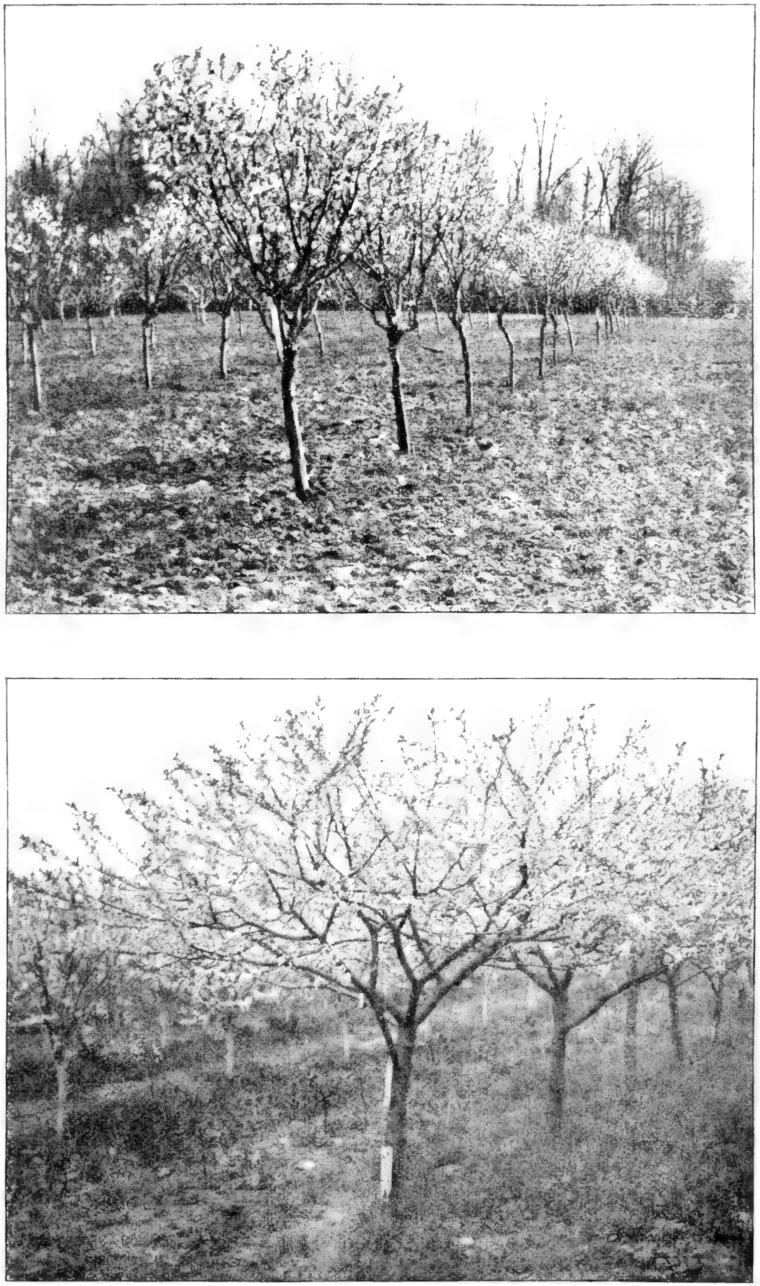

Plate XXVI.—Sulphur Washes: Effect of Fall Spraying on Plums. Upper, Reine Claude; Lower, Burbank.

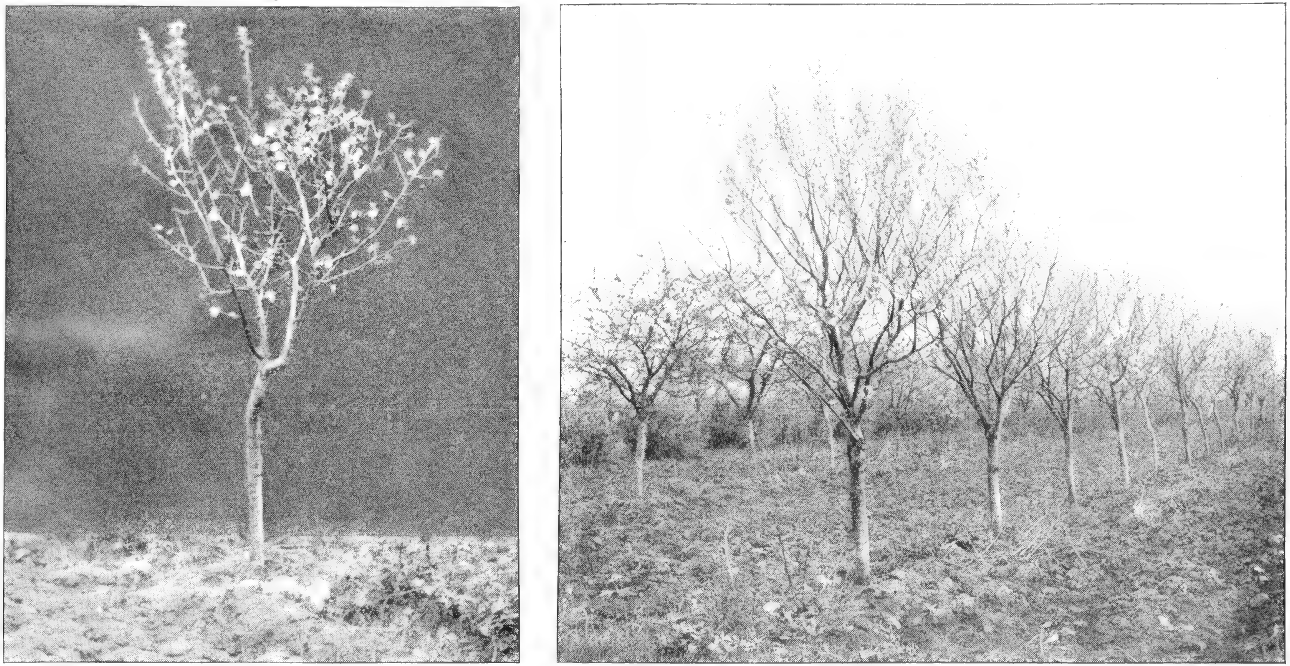

PLATE XXVII.—KEROSENE-LIME MIXTURES: EFFECT OF SPRAYING ON PLUMS.

The conditions governing the past year's experiment were more favorable for making the test. The wood was well ripened and the weather in the fall leading up to the spraying season was mild, while the winter was less destructive to fruit trees, especially those that were injured by insects and fungi. The applications of sulphur washes were, on the whole, not detrimental to the trees and kept the scale well in control.

From these results it is not safe to conclude that spraying in the fall is unattended with danger, as the resistance of a tree is largely determined by its health upon entering the winter. Likewise the kind of spray employed and the hardiness of the variety are important factors.

Whether or not it is advisable to spray in the fall seems to be a matter of expediency. A profitable orchard infested with scale will soon cease to be remunerative if neglected, and spraying, if it cannot be done in the spring, should be done in the fall; as the losses likely to follow will be more than compensated by the increased vigor of the trees and value of the fruit produced.

THE KEROSENE-LIME MIXTURE.

H. E. HODGKISS AND F. A. SIRRINE.

This is one of the comparatively new sprays that has been introduced for the control of the San Jose scale and has attracted considerable attention through the efforts of the Delaware Agricultural Experiment Station.[2] The kerosene-lime mixture is a mechanical emulsion of lime, kerosene and water, the lime acting as a carrier for the oil, while the water serves largely as the diluent. Kerosene is one of the most penetrating and destructive of insecticides, but when applied pure may cause severe injuries. In the employment of lime it has been thought that a combination has been secured by which the oil could be more safely used. In these experiments tests have been made with Limoid and various grade and superfine limes from Ohio and New York.

CONDITIONS.

As has been done in other experiments, blocks of bearing apple, peach, and plum trees were selected for treatment. With the exception of a few badly scale-encrusted trees the orchards in which the experiment was made were in a vigorous condition. The sprays were continued at irregular intervals during the spring and summer.

THE MIXTURES AND THEIR PREPARATION.

The mixtures were prepared in several percentages as follows:

10 per ct.,	kerosene	5	gal.,	lime	20	lbs.,	water	to	make	50 gal.
12½ per ct.	"	6¼	"	"	25	"	"	"	"	50 "
15 per ct.	"	7½	"	"	30	"	"	"	"	50 "
20 per ct.	"	10	"	"	40	"	"	"	"	50 "
25 per ct.	"	12½	"	"	50	"	"	"	"	50 "
30 per ct.	"	15	"	"	60	"	"	"	"	50 "
35 per ct.	"	17½	"	"	70	"	"	"	"	50 "
40 per ct.	"	20	"	"	80	"	"	"	"	50 "

The kerosene and lime were thoroughly mixed together into a thin " sloppy " mass and the required amount of water was added;

[2] Del. Agl. Exp. Sta. Press. Bulletin 14 (1904); Bul. 68 (1905).

after which the whole mixture was stirred vigorously in order that the entire "sloppy" mass should be thrown into suspension. It was then pumped back into itself with the spray pump for from three to five minutes to insure a thorough emulsification of the ingredients.

THE ORCHARDS.

The orchards in which the treatments were made are located in Ontario Co., at Geneva; in Suffolk Co., at Northville; and in Niagara Co., at Youngstown. The conditions were the same as those given in the previous section for Orchards II, IV and V. In addition an orchard was selected for the summer spraying in which the trees were about forty years old and very badly scale infested. At Youngstown a portion of an apple orchard of 400 trees which was infested with scale received the spring treatment with this mixture in comparison with the recognized standard sprays.

The total number of trees under experiment was 673, of standard varieties of apples, peaches and plums.

DISCUSSION OF EXPERIMENTS.

FALL TREATMENT.

Orchard IV: Plums.—In this orchard 63 Burbank and Reine Claude plums, and two small cherries were sprayed. These trees in the past had been very productive and were thrifty. Local hydrated lime was used and applications containing 10 per ct., 15 per ct., 20 per ct., 25 per ct., 30 per ct., 35 per ct. and 40 per ct. of oil were made. The preparations having the higher percentages of oil were applied with difficulty as the washes were very heavy because of the small quantity of water used in proportion to the amount of lime employed. For purposes of comparison some trees were treated with a 10 per ct. limoid-kerosene wash.

Results: Hydrated lime mixture, 10 per ct. oil.—This mixture was applied to 13 Reine Claude plums, each tree being numbered with respect to the order in which it was sprayed. On May 10 trees 1 and 2 were severely injured, the only evidence of life being scattering blossoms and leaves on the tips of the highest branches. With the coming of summer these trees gradually

weakened and on July 20 were dead. Early in the season trees 3-13 inclusive showed no injury, the leaves and blossoms being abundant and well distributed. Only a small percentage of the blossoms set fruit and the crop was small.

Limoid mixture, 10 per ct. oil.—This was sprayed on 9 Reine Claude plums. Trees 1 and 2 were dead on May 10, and tree 3 had no living spurs on the inner branches although the upper portions were well covered with foliage and blossoms. At this time trees 4-9 inclusive had on one side abundant foliage and blossoms, while the other half was devoid of blossoms, but had a heavy leafage. On July 20 trees 1 and 2 were dead while the remainder of the trees were sickly and bore a small yield of fruit.

Hydrated lime mixture, 15 per ct. oil.—Nine Reine Claude plums were sprayed and numbered as with the other treatments. Tree 1 was nearly dead when examined May 10; and tree 2 had a large number of blossoms in the upper portion, while the lower limbs had neither blossoms nor leaves. The third tree was heavily covered with blossoms and leaves on one side while on the opposite side the buds were only partially opened. The remainder of the trees had abundant foliage but few blossoms. On July 21, trees 1 and 2 were dead, tree 3 had one-half of the normal leafage and no fruits. Trees 4-9 inclusive had a large number of leaves and a very small crop of fruit.

Hydrated lime mixture, 20 per ct. oil.—This wash was applied to 9 Reine Claude plums and one small cherry. An examination early in the spring showed that about one-quarter of the buds were killed while the remainder were greatly retarded With the advance of spring the blossoms were scattered thinly over the trees. Only a few of these set fruits so that the yield was very small.

Hydrated lime mixture, 25 per ct. oil.—Nine Reine Claude plums were sprayed and all showed injury on May 10. Tree 1 was dead, trees 2-7 had only scattering leaves and blossoms, and the remaining trees were uninjured. The latter bore an average crop of fruit, while the former had none.

Hydrated lime mixture, 30 per ct. oil.—Applications were made to one Reine Claude plum, five Burbank plums and one small cherry tree. On May 10 tree 1 was about dead, tree 2 was in a similar condition, and the other trees were without blossoms but

had a heavy foliage. On July 21, 4 trees were dead, one severely injured, and the remaining trees were slowly dying. Later in the summer all the trees receiving the treatment were dead.

Hydrated lime mixture, 35 per ct. oil.—Applications of this were made to four trees. On May 10, tree 1 was dead and the foliage on trees 2 and 3 was sparse. Tree 4 had a good crop of leaves and blossoms, but matured about one-third of a crop of fruit.

Hydrated lime mixture, 40 per ct. oil.—Four Burbank plums were sprayed and at the first examination on May 10 showed considerable reduction in blossoms and leaves on the inside spurs, although the outer branches were well covered. These trees had about one-fifth of a crop of fruit.

In comparison with the above it is interesting to note the results on trees of the same variety in adjacent rows, which while they had been sprayed with the sulphur wash served as checks. These trees blossomed heavily and produced full yields.

Orchard V: Peaches.—A block of fifteen young thrifty peaches in a well cultivated orchard and another comprising 58 trees in a neglected condition were sprayed with the 10 per ct., 20 per ct. and 40 per ct. mixtures on Dec. 5. Scales were abundant on the neglected trees at the date of applying the washes.

Results: Limoid mixture, 10 per ct., 20 per ct., 40 per ct. oil.—In the spring the younger growth on all the trees receiving the applications showed somewhat more extensive injuries from winter-killing than the checks. On Oct. 23 of the following autumn Mr. Sirrine reported that the trees which received applications of the 10 per ct. and 20 per ct. oil were in no better condition with respect to the number of living scales than the checks, but that the bark was somewhat smoother owing to the removal of the old scales by the weathering off of the whitewash. The trees receiving the highest percentage of oil, while they showed some improvement over the checks, were well covered with young scales.

Effect on peach leaf curl.—In the spring following the treatment, the sprayed trees apparently had as much leaf curl as the checks. A count of the leaves on the sprayed trees showed an average of 76 per ct. of curled leaves, which was about the amount of the infestation of the checks.

SPRING TREATMENT.

Orchard IV: Plums.—Just before the buds opened a block of plums equal in number and similar in variety to those selected for treatment during the previous fall received an application of the 10 per ct. and 25 per ct. mixtures containing hydrated lime. The trees were slightly infested with scale.

Results.—When the buds opened these trees had more foliage and blossoms than the fall-sprayed portion, but a greater variability in the condition of the different varieties was quite noticeable. Burbank plums which had abundant foliage and blossoms soon turned brown and in a few weeks were dead. Other trees of the same variety had no blossoms but heavy foliage, and remained healthy throughout the summer. Reine Claude plums and cherries showed a greater variation. All the trees blossomed, some very slightly, but the amount of fruit in each case was not large. Small fruits, such as currants and raspberries, planted between the trees were either killed or so badly injured by the spray that they produced no fruit.

Orchard V: Apples.—In this orchard five large apple trees which were in a neglected condition as regards scale were treated with the 20 per ct. and 40 per ct. mixtures.

Results: Limoid mixture, 20 per ct., 40 per ct. oil.—During the summer following, the treated trees were not in as healthy condition as the checks, as the foliage was less abundant and off color. At the last examination the trees receiving the application of the 20 per ct. oil were as badly scale-infested as the checks. The 40 per ct. oil was more effective on the scale and in addition seemed to aid in clearing the bark of lichens and moss.

Orchard VI: Peaches.—At Laurel, in Suffolk Co., 45 scale-incrusted peaches were sprayed with the 10 per ct,. 20 per ct. and 40 per ct. mixtures.

Results: Limoid mixture, 10 per ct., 20 per ct. 40 per ct. oil.—The weaker percentages did not appreciably lessen the number of mature female scales, while the 40 per ct. mixture proved to be somewhat more destructive. On Oct. 23 larvæ and mature scales were abundant on sprayed and unsprayed trees.

Effect on curl.—Peach leaf curl was very abundant on the treated as well as on the untreated trees.

Orchard VII: Apples.—In a well cultivated orchard near Geneva, 130 trees were sprayed with either the kerosene-lime

mixture or with one of the sulphur washes to determine their comparative merits for the control of the scale which was quite abundant in the orchard. The 25 per ct. oil mixture was used on twenty-four trees, and after the falling of the blossoms twelve of these were given the second and third treatments with the bordeaux-arsenical mixture. The remainder of the orchard was sprayed with several sulphur washes during the dormant season and after the falling of the blossoms the usual applications of the bordeaux mixture, containing an arsenical poison, were made to a number of these trees.

Results.—With the opening of the buds no apparent injuries were noticeable on any of the trees. On Oct. 12 the apples were picked. The yields from the trees treated with the kerosene-lime wash showed an average infestation by the scale of 98.2 per ct. while the fruit from the trees sprayed with the lime-sulphur wash had an average infestation of 9.8 per ct. The checks were completely infested. The fruit from the section treated with the oil spray, without the bordeaux-arsenical mixture, were 19.8 per ct. scabby as compared with 1.3 per ct. of scabby apples taken from the trees receiving treatment with the oil and the bordeaux mixture. The fruit from the trees sprayed with sulphur wash only, were 4.7 per ct. scabby, while those from the trees receiving applications of the sulphur wash and the bordeaux mixture had an average of 3.2 per ct. of scab. The checks had 28.5 per ct. of scabby fruit.

Trees treated with the oil spray only, had 21.1 per ct. of the fruit injured by larvæ of the codling moth, while those sprayed with the bordeaux-arsenical mixture in addition showed two per ct. injury by this insect. The fruit from the trees treated with sulphur wash only was 56.6 per ct. wormy as compared with an average of 17.7 per ct. wormy fruit from the trees receiving one application of the sulphur wash, supplemented by the second and third treatments with the bordeaux mixture. The checks had 30.7 per ct. of wormy fruit.

Orchard VIII: Apples.—In Youngstown, Niagara County, a portion of a thrifty bearing orchard of 400 trees received applications of the 25 per ct. kerosene-lime mixture. At the time of spraying scale was abundant on the trees.

Results: Hydrated lime, 25 per ct. oil.—Of 69 trees receiving applications of this wash 15 showed on May 20 severe injuries to

one side while the other portion had an abundance of leaves and blossoms. Trees in this orchard which received applications of the sulphur washes were in a very satisfactory condition. The effects of the kerosene-lime mixture on scale, as would be determined by the extent of the spotting of the fruit, was not satisfactorily shown owing to an unusually small crop of apples which was generally clean through the entire orchard.

SUMMER TREATMENT.

Orchard IX: Apples.—For this experiment an orchard was selected in Geneva which was very badly infested with the scale. The trees under observation were twelve Baldwins and Greenings divided equally as regards variety and about 40 years old.

In connection with the treatment for scale an experiment was conducted to determine the comparative merits of various grades of lime in the preparation and use of the kerosene-lime mixtures.

CONDITIONS.

In the experiment the 10 per ct. oil mixture was used, being prepared with the grade and superfine Limoid, and the grade and superfine Marblehead lime. The mixtures were made in 50-gallon lots and each lot was applied separately. In order to ascertain its condition after preparation and while being sprayed, samples were taken of each lot after emulsification and at equal intervals at the discharge from the nozzle.

The wash was applied on June 11, at which time the foliage was heavy and the fruit of a good size. The weather during the day was hot with showers at intervals. The results are as follows:

THE MIXTURES.

Limoid, superfine.—Three 50-gallon lots were prepared by the common method. This lime formed a smooth paste with the oil, and after the addition of water and agitation by the pump a complete emulsion was apparently made. Fifteen samples taken in 1,000 c.c. cylinders from the three different lots showed the following results with respect to the relative proportions of lime-oil emulsion, free oil, water and lime in each container. Attention is directed to the interesting fact that whitewash without the lime and oil emulsion was being sprayed on the trees at intervals during the application of lots 2 and 3 while in the application of lot 1 nearly one-half of the mixture was lime-oil emulsion.

TABLE I. QUANTITY OF EMULSION, FREE OIL, WATER, AND LIME IN THE SUPERFINE LIMOID MIXTURE TAKEN IN 1000 C. C. CYLINDERS.

LOT.	Sample.	Emulsion.	Free oil.	Water.	Lime (precipitate).
	No.	C. c.	C. c.	C. c.	C. c.
I.	1	500	....	300	200
	2	450	....	100	450
	3	450	....	100	450
	4	450	....	100	450
	5	500	....	300	200
II.	1	185	15	600	200
	2	....	....	800	200
	3	....	....	800	200
	4	....	....	800	200
	5	150	10	600	240
III.	1	375	....	375	250
	2	250	....	500	250
	3	....	....	1,000	....
	4	....	....	625	375
	5	500	....	325	175

Limoid, grade.—Five 50-gallon lots were prepared by the common method. This lime formed a creamy mass with the oil, which, upon the addition of the water followed with agitation by the pump, gave a mixture with no free oil. The oil was apparently completely emulsified. The emulsion, however, was not evenly distributed in the mixture, as the table shows.

TABLE II. QUANTITY OF EMULSION, FREE OIL, WATER, AND LIME IN THE GRADE LIMOID MIXTURE TAKEN IN 1000 C. C. CYLINDERS.

LOT.	Sample.	Emulson.	Free oil.	Water.	Lime. (precipitate)
	No.	C. c.	C. c.	C. c.	C. c.
I.	1	666	....	131	203
	2	....	....	750	250
	3	250	....	500	250
	4	250	....	500	250
	5	125	....	625	250
II.	1	400	....	440	140
	2	....	....	750	250
	3	650	....	165	175
	4	150	....	700	150
	5	125	....	625	250
III.	1	325	....	465	210
	2	125	....	675	200
	3	125	....	675	200
	4	180	....	675	130
	5	210	....	600	165
IV.	1	200	....	635	130
	2	....	....	800	200
	3	165	....	650	185
	4	15	....	920	65
	5	125	....	625	250
V.	1	335	....	410	255
	2	....	....	1,000	....
	3	....	....	440	560
	4	250	....	575	175
	5	150	....	640	210

Marblehead lime, superfine.—Five 50-gallon lots were prepared by the common method. This lime formed an uneven lumpy paste when mixed with the oil and did not retain oil satisfactorily after agitation was applied. Repeated attempts to make a good mixture resulted in failure. In the following table may be seen the variation in the various mixtures as shown by 25 samples taken from the five different lots:

TABLE III. QUANTITY OF EMULSION, FREE OIL, WATER, AND LIME IN THE SUPERFINE MARBLEHEAD LIME MIXTURE TAKEN IN 1000 C. C. CYLINDERS.

LOT.	Sample.	Emulsion.	Free oil.	Water.	Lime (precipitate).
	No.	*C. c.*	*C. c.*	*C. c.*	*C. c.*
I....................	1	500	....	360	140
	2	Trace......	....	668	342
	3	....	....	800	200
	4	....	....	833	167
	5	Trace......	....	800	100
II....................	1	333	....	467	200
	2	5	....	595	400
	3	....	5	200	795
	4	332	....	428	250
	5	500	263	125	112
III....................	1	....	250	625	125
	2	....	125	625	250
	3	....	....	800	200
	4	125	163	562	150
	5	400	100	375	125
IV....................	1	250	....	625	....
	2	....	125	625	125
	3	....	....	800	200
	4	125	163	562	150
	5	423	75	325	187
V....................	1	475	....	380	145
	2	5	....	660	335
	3	....	....	750	250
	4	....	5	200	795
	5	Trace......	....	800	200

Marblehead lime, grade.—This lime was prepared in four 50-gallon lots. The lime formed a white pasty mass which did not retain the oil on the addition of water followed with agitation. The force of the pump appeared to drive the oil from the lime. As with the preceding lime the attempts to produce a complete emulsion resulted in failure. A comparison of 16 samples taken from the four lots will show the extreme variation of the mixture made with this lime.

TABLE IV. QUANTITY OF EMULSION, FREE OIL, WATER, AND LIME IN THE GRADE MARBLEHEAD LIME TAKEN IN 1000 C. C. CYLINDERS.

LOT.	Sample.	Emulsion.	Free oil.	Water.	Lime (precipitate).
	No.	C. c.	C. c.	C. c.	C. c.
I	1	625	38	337	442
	2	363	20	175	125
	3	200	50	625	162
	4	150	13	675	150
II	1	313	20	650	17
	2	.....	.....	125	875
	3	200	50	500	250
	4	300	25	588	87
III	1	300	25	650	20
	2	.....	.....	125	825
	3	50	125	825	.....
	4	150	15	675	162
IV	1	425	50	513	12
	2	.....	.....	115	885
	3	200	50	625	125
	4	.....	.....	902	38

Effect on trees.—The grade and the superfine limoid and the superfine Marblehead mixtures caused some spotting and burning of the leaves and fruit which was accompanied with serious dropping of the leaves. Some of the trees had the foliage badly burned, while others treated by the same preparation showed no such injury. The grade Marblehead lime mixture caused more serious injury to the foliage and branches than any of the other washes. The injuries to the fruit, leaves, and young growth appeared very soon after the treatment.

Effect on scale.—None of the washes appeared to be constantly effective in destroying the scale. While some applications gave satisfactory results in this respect, many treated trees were at the end of the season as badly infested as the checks. There was no practical difference in the effectiveness of the several mixtures. The irregularities seem largely attributable to the instability of the emulsion and its uneven distribution in the wash.

SUMMARY AND CONCLUSIONS.

The experiments with the kerosene-lime mixture during the past year show that the applications of this wash have given variable results upon trees and scale. The lower percentages of oil were generally ineffective on scale but the mixtures containing higher percentages of oil were more efficient. The comparative test with

various limes showed that the best results were obtained by the use of limoid.

The percentages of kerosene in well prepared mixtures were determined by Mr. Baker, as given in detail in the next section. These determinations indicated that the larger percentage of oil is formed into an emulsion with a portion of the lime which remains in suspension, while the remainder of the oil, which is small in quantity, is carried to the bottom by the lime which settles. Probably the chief reason for the variable results upon scale attending the application is the imperfect distribution of the emulsified lime-oil portion in the mixture.

While the use of the kerosene-lime wash in this work has on the whole proven unsatisfactory, it is intended to continue the experiments next season to determine if a safe and efficient combination of the oil and lime can be made.

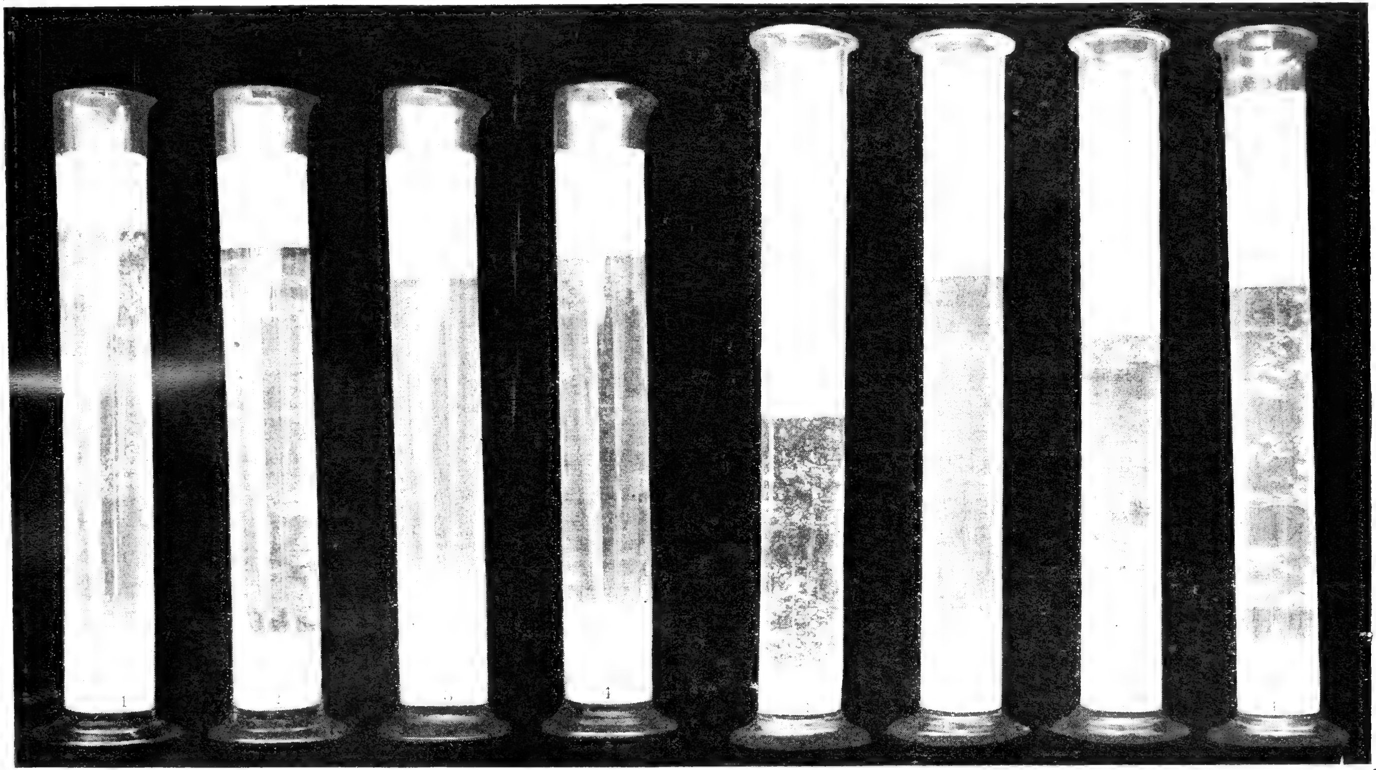

Plate XXVIII.—Duplicate Samples of Kerosene-Lime Mixtures Showing Variation in Contents: No. 1, Superfine Marblehead Lime; No. 2, Superfine Limoid; No. 3, Grade Limoid; No. 4, Grade Marblehead Lime.

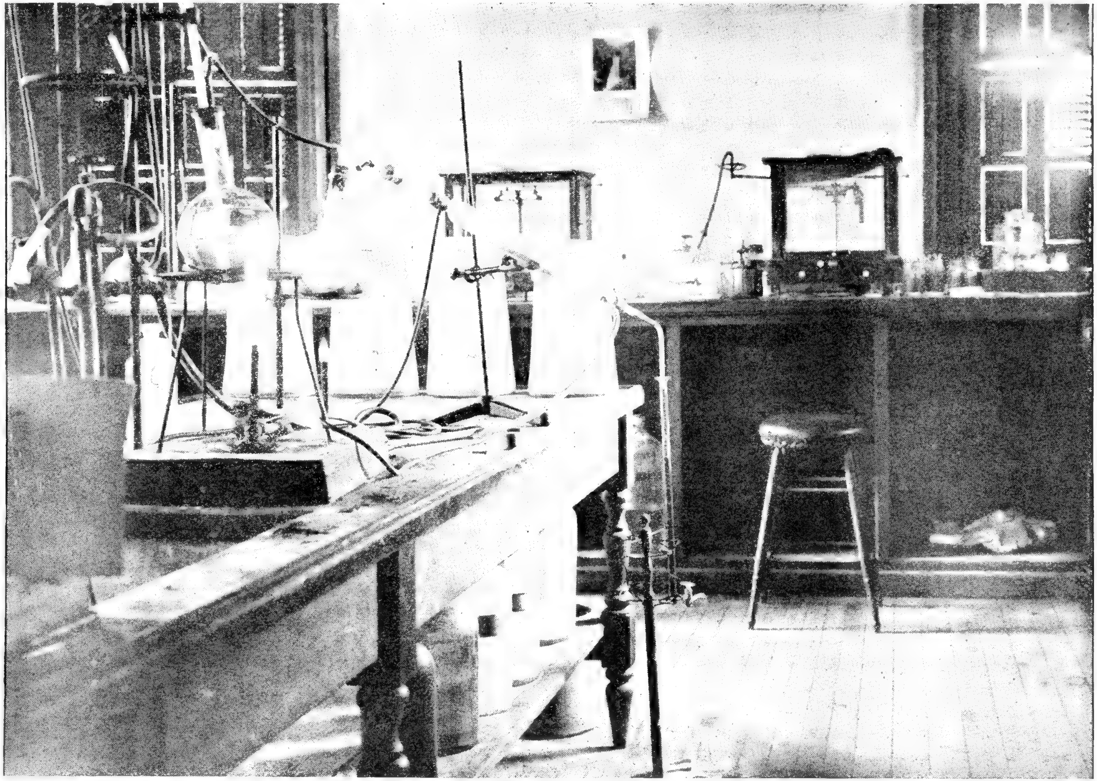

Plate XXIX.—The Kerosene-Lime Mixture: Apparatus Used in Determining the Kerosene Content. The Burette Contains the Layer of Water, Below, and the Layer of Oil, Above.

DETERMINATION OF KEROSENE IN THE KEROSENE-LIME MIXTURE.

E. L. BAKER.

When lime, kerosene and water are mixed in certain proportions, it has been shown that an emulsion is formed, and that the whole mixture, after agitation ceases, separates into three layers. Because of this separation there may be unequal distribution of the ingredients of the mixture in spraying, and for this reason it was thought a matter of interest to determine both the quantity of kerosene present in each of these layers, and the relative proportion of kerosene held in emulsion when different limes are used.

Four different mixtures were examined. These were prepared according to the 10 per ct. formula previously given, using the following limes: (I) Superfine Marblehead lime, (II) grade Limoid, (III) superfine Limoid, (IV) grade Marblehead lime.

After thorough agitation, a one-gallon sample was immediately taken from each of the mixtures and put into large glass jars. The contents of these jars were thoroughly stirred and then poured into separatory funnels. In ten to fifteen minutes three distinct layers formed. These were separated by drawing off each successively into flasks which were then tightly corked to prevent evaporation.

METHOD OF DETERMINATION.

A quantity of the lime-kerosene mixture is weighed into a flask, which is connected to a condenser, and steam is passed into it. The kerosene all distils over and forms a separate layer above the water which passes over with it. The distillate is allowed to drop into a burette, from which the lower layer of water is drawn away from time to time. After the distillation is complete, the amount of kerosene may be read in cubic centimeters. This reading multiplied by the specific gravity of the kerosene, which

has been previously taken, gives the weight. Knowing the weight of the mixture taken, the percentage of kerosene can easily be calculated.

Plate No. XXIX gives a view of the apparatus and shows the layer of kerosene in the burette.

PRELIMINARY DISTILLATIONS.

In order to show that this method was quantitative for kerosene, two trial distillations are made. First, 5 c. c. of kerosene was measured into a 500 c. c. flask by means of a pipette and distilled with steam for about two hours; at the end of which time it was found that the entire 5 c. c. had passed over. A duplicate distillation was made giving precisely the same result.

Next a small mixture of lime, kerosene and water was made up as follows:

Kerosene	10	c. c.
Water	88.9	c. c.
Lime	4.5	grams.

This mixture is in the same relative proportion as the 10 per ct. kerosene-lime mixture. In this case, as in the previous experiment, all of the kerosene passed over.

These trial distillations show that by this method the entire amount of kerosene is obtained.

DISTILLATION OF LAYERS.

Twenty-five to thirty grams of each of the lower layers were weighed out in duplicate and distilled according to the method described above. Practically all of the kerosene, about 1 c. c. in each case, passed over in one hour, but the distillation was continued for an hour longer to get the last traces of the oil.

Fifteen to twenty grams of the upper layer were weighed out and distilled in the same way. The time of distillation, however, was much longer, from six to eight hours, and 10 to 15 c. c. of kerosene passed over.

Similar distillations of the middle layers were made, but no kerosene was found.

The condition of all the layers with regard to the kerosene content is given below in the tabulated results:

TABLE V. KEROSENE IN DIFFERENT PORTIONS OF KEROSENE-LIME MIXTURES.

LOT AND SAMPLE.	Weight.	Kerosene distilled.	Specific gravity.	Weight of kerosene.	Percentage of kerosene.
	Grams.	*C. c.*		*Grams.*	*Per ct.*
LOWER LAYERS:					
I	31.13	1.1	.79	.869	2.79
	32.15	1.2	.79	.948	2.96
II	27.58	1.1	.79	.869	3.15
	27.85	1.05	.79	.830	2.99
III	35.89	1.1	.79	.869	2.42
	39.47	1.25	.79	.988	2.50
IV	23.40	.7	.79	.553	2.36
	24.56	.7	.79	.553	2.25
UPPER LAYERS:					
I	20.42	15.9	.79	12.56	61.50
	20.54	16.1	.79	12.72	61.92
II	16.24	10.1	.79	7.98	49.12
	15.64	10.	.79	7.90	50.51
III	15.09	11.	.79	8.69	57.59
	15.31	11.	.79	8.69	56.76
IV	18.46	14.3	.79	11.30	61.19
	20.82	16.5	.79	13.035	62.60

From the above results it will be seen that by far the greater part of the kerosene is found in the uper layer, while only a small portion of the oil is carried to the lower by the lime as it settles down.

The percentage of kerosene in the top layers varies somewhat with the different limes used. This difference is not noticeable in the lower layers.

SCALECIDE.

H. E. HODGKISS.

The soluble oil preparations are comparatively new sprays which during the past year have been widely advertised for the treatment of the San Jose scale. There are now several brands on the market, to each of which a proprietary name has been given. As opportunity has permitted, rather extensive tests have been made with these preparations to determine their merits as compared with standard remedies. As the work with it has been longer continued, the following notes on the results with Scalecide, one of the first of the brands to be introduced, are given to indicate the probable value of the miscible oils for orchard treatment. Applications of Scalecide were made during the dormant season and were continued at irregular intervals throughout the summer and fall. The work being in progress at the present time, the results from the fall treatment cannot be obtained.

CONDITIONS OF TESTING.

On April 26 when the buds were swelling, a block of 20 apples, 5 pears, 1 peach and 1 quince was sprayed with various percentages of the oil. Apples and peaches were badly scale-infested while the other kinds of fruit had only a few traces of scale.

PREPARATION OF THE MIXTURES.

Percentage	of oil,	3 per ct.:	Scalecide,	3/4	gal.;	water,	25	gals.
"	"	5 per ct.:	"	1	"	"	20	"
"	"	7 1/2 per ct.:	"	1 1/2	"	"	20	"
"	"	10 per ct.:	"	2	"	"	20	"
"	"	15 per ct.:	"	3	"	"	20	"

The oil and water were stirred vigorously, after which the mixture was pumped back into itself until the Scalecide which first appeared on the surface was completely mixed with the water.

DISCUSSION OF TREATMENTS AND RESULTS.

EARLY SPRING APPLICATION.

Five per ct. Scalecide: Apples.—On April 26, seven trees were sprayed with the five per ct. wash. The buds at this time were slightly swollen. The weather for the week following the application was clear, with slightly increasing temperature. The buds on the check trees opened rapidly during the first week of May but the treated trees were not as far advanced. On May 15, 45 per ct. of the buds on the sprayed trees were not open while the checks were in full foilage. During the following two weeks the former were greatly improved in appearance, and by August 15 the foliage on them seemed to be more abundant than that on the unsprayed trees.

Plums.—Three plum trees sprayed on April 26 were examined on May 15. There was no difference at this time between the checks and treated trees and these conditons continued the same throughout the summer.

Pears.—Three pear trees treated before the buds opened showed severe retardation during the early part of May. A careful examination at that time showed that about 75 per ct. of them were well open. Four weeks later these buds had fully developed, and the only trace of injury was the relatively less abundance of the leaves on the inner and lower spurs.

Ten per ct. Scalecide: Apples.—For this application seven badly infested apple trees were selected. These were sprayed April 26. On May 10 about 15 per ct. of the buds had opened while others were somewhat retarded. As the season developed the effect of the oil became less noticeable, and by the first of June the foliage was heavy and of a good color.

Peach.—A five year old peach tree, much infested, was selected for treatment. In making this treatment only one-half of the tree was sprayed while the remaining half was left as a check. As the buds opened no difference could be detected between sprayed and unsprayed portions except that there was a slight retardation by the treatment.

Two weeks later the entire tree was in full foliage and no difference could be seen between the two portions. On August 1 the leaves on the checks were beginning to drop and by September

this portion was completely defoliated, while the sprayed portion retained its foliage until the appearance of frosts.

Pears.—Observations on May 16 showed that pear trees receiving this treatment had about 54 per ct. of the buds retarded. As the season advanced these buds opened and the foliage ultimately equalled that of the checks.

Fifteen per ct. Scalecide: Apples.—Seven trees were treated just before the buds commenced to swell. An examination on May 15 showed that about 75 to 100 per ct. of the buds were retarded. With the advancing spring this difference became less apparent and in the late summer the foliage was much better than that of the checks.

Pears.—An application of this percentage to four trees gave results similar to those obtained with the apples described above. The trees, however, made a vigorous growth during the summer.

SUMMER APPLICATIONS.

Beginning June 20, a series of applications was made to apples, pears, peaches and plums using the 3 per ct., 5 per ct. and 7½ per ct. solutions. During the few days following each spraying the weather conditions were very favorable.

Results: On peaches, 3 per ct., 5 per ct. and 7½ per ct. Scalecide.—The foliage on the trees receiving applications of the 3 per ct. Scalecide showed severe burning. The general appearance of the leaves was as if punctured by hail stones. The fruit which had become sizable was uninjured.

The five per ct. solution affected the foliage in a manner somewhat similar to that described above. The fruit however was badly burned and did not develop.

Applications of the 7½ per ct. Scalecide entirely defoliated the trees.

On apples, with 3 per ct., 5 per ct. and 7½ per ct. Scalecide.—The apple leaves on the trees receiving the several treatments were severely burned and the fruit marked with black corky spots. The injured fruits grew to a good size but were imperfect. The injury by the different sprays was equally severe.

On pears, with 3 per ct., 5 per ct. and 7½ per ct. Scalecide.—Pears were injured in much the same manner as the apples. The

injury to the fruit however became less prominent as the season advanced. All the treatments caused an equally severe injury.

On plums, with 3 per ct., 5 per ct. and 7½ per ct. Scalecide.— The applications of the 5 per ct. and 7½ per ct. strengths seemed safe. But later in the summer further experiments were made to determine if the oils were uniformly safe to plum foliage. In this work the results were quite different, for the fruit was badly spotted and the leaves burned, which resulted in severe defoliation.

EFFECT ON SCALE.

The trees receiving treatment during the dormant season appeared to be entirely free from living scale when examined during June, July, and the first week in August. During the last week in August young living scales were detected upon the trees receiving applications of 5 per ct. and 10 per ct. oil. No living scales were seen on the trees sprayed with the 15 per ct. oil at any time during the summer. The appplications containing 3 per ct. Scalecide seems to have little or no effect upon the scale.

SUMMARY.

A careful examination of the results obtained by the use of this oil showed that spraying during the dormant season was accompanied with a great retardation of the buds. But later these opened so that ultimately there was little difference in this respect between the sprayed and unsprayed trees. The results in this particular attending applications of 5 and 10 per ct. Scalecide were not important, but the retardation following the treatment with the 15 per ct. oil was very severe. In many cases the treatment seemed to promote the growth of better foliage. Summer spraying with Scalecide in every instance caused severe injuries. In these experiments, 3 per ct. Scalecide had no appreciable effect on the scale. Applications containing 5 per ct. and 10 per ct. oil seemed to destroy from 80 to 95 per ct. of the scale. The higher percentage seemed to entirely control the scale.

While the Scalecide at first gave promising results, it seems best in view of the variable results upon scales and trees in all instances in the later work to continue these tests to determine its merits as an orchard spray.

REPORT

OF THE

Horticultural Department.

[1]U. P. Hedrick, *Horticulturist.*

[2]S. A. Beach, *Horticulturist.*

N. O. Booth, *Assistant.*

O. M. Taylor, *Foreman.*

TABLE OF CONTENTS.

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[1] Appointed August 1, 1905.

[2] Resigned September 1, 1905.

REPORT OF THE HORTICULTURAL DEPARTMENT.

PART I. PLANT-FOOD CONSTITUENTS USED BY BEARING FRUIT TREES.*

L. L. VAN SLYKE, O. M. TAYLOR AND W. H. ANDREWS.

SUMMARY.

1. Object. The work described in this bulletin was undertaken for the purpose of ascertaining the amounts of nitrogen, phosphoric acid, potash, lime and magnesia used in one growing season by bearing fruit trees.

2. Kinds of trees studied. We selected for the work one to three standard varieties of each of the following kinds of fruit trees: Apple, peach, pear, plum and quince. The trees were typical representatives in the full vigor of bearing.

3. Plan of work. The fruit, leaves and new growth of wood as represented by the tips of branches were carefully gathered, weighed, dried and analyzed in the case of each individual tree.

4. Presentation of results. Tables are given showing the amount of each of the plant-food constituents in the different portions of each of the trees. The relations of the tabulated data presented are discussed in detail.

5. Plant-food used per acre. Peach trees used the largest amounts of plant-food; apple and quince trees, approximately alike in the results given, come second, while pear and plum trees, which give results much alike, come third.

6. Relative proportions of plant-food constituents used. Using one pound of nitrogen as a basis for comparison, it was found that the different fruit trees used very nearly the same

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relative proportions of the different plant-food constituents. The averages were as follows:

Nitrogen, 1 pound.
Phosphoric acid, .27 pound
Potash, 1.14 pounds
Lime, 1.35 pounds
Magnesia, 0.45 pound

INTRODUCTION.

The problem of feeding plants in the most effective and, at the same time, economical way is more complicated than any other we have to deal with in ordinary agricultural operations. Assuming that the physical properties of the soil are satisfactory, we ought to know, in order to solve the problem most satisfactorily, two important factors—first, the amount of plant food required by crops, and second, the amount of available plant food which the soil can be relied upon to furnish during the growing season. It is less difficult to secure knowledge regarding the former question. Much study has been, and is being, given to the latter point, the determination of the amount of available plant food in soil, but a thoroughly reliable method cannot be said to have been found yet.

The work presented in the first part of this bulletin was undertaken at the suggestion of the Director and its object was to study one of the factors indicated above, viz., to ascertain the amounts of certain plant-food constituents used in one growing season by fruit trees in bearing. For a strictly complete study, we ought to know the amount of plant food used during the growing season by the fruit, leaves, new growth of wood, increase in size of trunk, branches and roots. So complete an investigation is impracticable, and we have to content ourselves with the results given by the fruit, leaves and new growth of branches. The plant food contained in these undoubtedly includes much the larger part of the total used by the whole tree.

The evidence furnished by chemical analysis of a given crop cannot be interpreted rigidly as showing how much plant food is actually required for that crop under any and all conditions. When there is an abundant supply of any form of plant food, a

plant may use more than it actually needs; that is, the same crop may thrive just as well in every respect, when it is supplied with less plant food than is indicated by a particular analysis. However, multiplication of data of this character is necessary in order that some kind of a general guide may be furnished for studying the plant-food requirements of crops. We need only be on our guard to interpret such data with some degree of freedom and not regard each analysis as representing all conditions.

The kinds and varieties of fruit trees used in our work were the following: Apple, Rhode Island *Greening* and **Baldwin;** peach, Champion, Elberta and Hills Chili; pear, Kieffer and Angouleme, *Duchess de*; plum, Grand Duke and Italian Prune; quince, Champion. The trees were selected with reference to securing typical representatives in the full vigor of bearing. The fruit, leaves and new growth of wood as represented by the tips of branches were carefully obtained, weighed, dried and analyzed. Precautions were taken when necessary, to avoid the loss of foliage, by enclosing the entire tree with mosquito netting. A record was kept of the fruit that fell before the final picking. The fruit was picked at the stage of ripeness usual in common practice. The foliage was left until it showed a tendency to drop. The twigs of new wood were removed soon afterward.

THE AMOUNTS OF PLANT-FOOD PRESENT IN ONE SEASON'S GROWTH.

We will consider by itself each kind of fruit used in our work. In the stone fruits, the pulp and stone were separated. The water given in the tables indicates simply the amount present in the different parts of the tree at the time the samples were taken.

APPLE TREES.

The following table gives the results secured with the two apple trees used in the work. The apple trees were about thirty years old.

TABLE I.—PLANT FOOD USED IN ONE SEASON BY APPLE TREES.

VARIETY.	Part.	Weight.	WEIGHT.					
			Water.	Nitrogen.	Phos'ic acid (P_2O_5).	Potash (K_2O).	Lime (CaO).	Magnesia (MgO)
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Baldwin......	Fruit..........	1,168.31	1,000.54	0.467	0.210	1.156	0.070	0.164
Greening.....	Fruit..........	1,542.19	1,338.70	0.679	0.278	1.418	0.154	0.200
Baldwin......	Leaves........	80.00	30.26	0.920	0.138	0.215	1.536	0.518
Greening.....	Leaves........	81.05	39.18	0.811	0.137	0.327	1.304	0.414
Baldwin......	New wood.....	5.88	3.04	0.026	0.009	0.013	0.082	0.014
Greening.....	New wood.....	8.19	4.33	0.037	0.013	0.019	0.088	0.018
Baldwin......	Total weight...	1,254.19	1,033.84	1.413	0.357	1.384	1.688	0.696
Greening.....	Total weight...	1,631.43	1,382.21	1.527	0.428	1.764	1.546	0.632

Attention is called to the following statements in connection with this table:

(1) *Weight.*—The fruit forms the largest weight of material taken from the trees, the leaves coming second. The total amount of dry matter in the products averages 234.75 pounds for each tree, distributed as follows: In the fruit, 185.6 pounds or 79 per ct. of the whole; in the leaves, 45.8 pounds or 19.5 per ct. of the whole; and in the new wood, 3.35 pounds, or 1.5 per ct. of the whole.

(2) *Nitrogen.*—The largest amount of nitrogen is contained in the leaves, the amount of nitrogen in the fruit being second. The total amount of nitrogen in the products averages about 1.5 pounds to a tree and is distributed as follows:—In the leaves, 0.87 pound or 59 per ct.; in the fruit, 0.57 pound or 39 per ct.; and in the new wood, 0.03 pound or 2 per ct.

(3) *Phosphoric Acid* is contained in largest amount in the fruit and in least amount in the new wood. Its total amount averages 0.4 pound and is distributed in the different portions of each tree on an average as follows:—In the fruit, 0.25 pound or 62.5 per ct.; in the leaves, 0.14 pound or 35 per ct.; and in the new wood, 0.01 pound or 2.5 per ct.

(4) *Potash.*—The total amount of potash in the products of each tree averages 1.57 pounds, distributed as follows:—In the fruit, 1.3 pounds or 82 per ct.; in the leaves, 0.27 pound or 17 per ct.; and in the new wood, 0.02 pound or 1 per ct.

(5) *Lime.*—The total amount of lime in the products of each tree averages 1.62 pounds, 1.42 pounds or 87.5 per ct. being found in the leaves.

(6) *Magnesia.*—The total amount of magnesia in the products of each tree averages 0.66 pound, 0.46 pound or 70 per ct. being

found in the leaves, and about 0.2 pound or 27.5 per ct. being present in the fruit.

(7) *Relative proportions of constituents.*—Taking the total quantities of constituents given above as an average, we have approximately the following relative proportions of the different constituents, based on 1 pound of nitrogen for comparison:

	Pounds
Nitrogen	1.0
Phosphoric acid	0.25
Potash	1.0
Lime	1.0
Magnesia	0.5

(8) *Amounts of different constituents used by one tree.*—On the basis of the results presented above, each apple tree uses on an average the following approximate amounts of plant-food constituents during the growing season:

	Pounds.
Nitrogen	1.5
Phosphoric acid	0.4
Potash	1.6
Lime	1.6
Magnesia	0.7

PEACH TREES.

The following table gives the results secured with three varieties of peach trees. The Elberta tree was 9 years old, and the other two were 7 years old.

TABLE II.—PLANT FOOD USED IN ONE SEASON BY PEACH TREES.

VARIETY.	Part.	Weight.	WEIGHT.					
			Water.	Nitrogen.	Phos'ic acid (P_2O_5.)	Potash (K_2O).	Lime (CaO).	Magnesia (MgO)
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Champion	Fruit pulp	123.39	110.20	0.118	0.043	0.257	0.009	0.021
Elberta	Fruit pulp	190.48	169.14	0.112	0.078	0.286	0.023	0.030
Hills Chili	Fruit pulp	171.26	154.89	0.130	0.070	0.337	0.014	0.029
Champion	Stones	6.42	2.56	0.014	0.004	0.006	0.002	0.003
Elberta	Stones	15.40	5.03	0.039	0.012	0.010	0.004	0.010
Hills Chili	Stones	8.05	2.40	0.026	0.007	0.006	0.003	0.007
Champion	Leaves	46.28	29.83	0.438	0.069	0.372	0.694	0.202
Elberta	Leaves	38.26	24.40	0.298	0.054	0.116	0.811	0.254
Hills Chili	Leaves	52.71	34.44	0.524	0.079	0.333	0.859	0.256
Champion	New wood	13.94	7.45	0.063	0.014	0.033	0.163	0.026
Elberta	New wood	5.50	2.72	0.024	0.007	0.012	0.091	0.014
Hills Chili	New wood	19.06	11.96	0.077	0.019	0.038	0.180	0.026
Champion	Total weight	190.03	150.04	0.633	0.130	0.668	0.868	0.252
Elberta	Total weight	249.64	201.29	0.473	0.151	0.424	0.929	0.308
Hills Chili	Total weight	251.08	203.69	0.757	0.175	0.714	1.056	0.318

A study of the foregoing table suggests the following statements:

(1) *Weight.*—The fruit constitutes the largest weight of the products taken from the tree. The total weight of dry matter removed is on an average 45.25 pounds for each tree, distributed as follows: in the fruit pulp 17 pounds or about 38 per ct. of the whole; in the peach stones, about 6.5 pounds or 14.5 per ct. of the whole; in the leaves, about 16 pounds or 35.5 per ct. of the whole; in the new wood, about 5.5 pounds or 12 per ct. The peach stones form about 6 per ct. of the fruit.

(2) *Nitrogen.*—The leaves contain the largest amount of nitrogen. The average amount of nitrogen removed from the tree by the products is about 0.6 pound, of which there is present in the fruit pulp 0.12 pound or 19.3 per ct. of the whole nitrogen; in the peach stones, about 0.03 pound or 4 per ct. of the whole nitrogen; in the leaves 0.42 pound or 67.7 per ct.; and in the new wood, about 0.06 pound or 9 per ct. of the whole nitrogen removed.

(3) *Phosphoric acid.*—The average amount of phosphoric acid contained in the products removed from the tree is 0.15 pound, of which 0.06 or 42 per ct. is found in the fruit pulp; .008 pound or 5 per ct. in the peach stones; 0.07 pound or 44 per ct. in the leaves; and .001 or 9 per ct. in the new wood.

(4) *Potash.*—The average amount of potash in the products of each tree is 0.6 pound, distributed as follows: In the fruit pulp, 0.29 pound or 49 per ct.; in the peach stones, .007 pound or 1 per ct.; in the leaves, 0.27 pound or 45 per ct.; and in the new wood, 0.03 pound or 5 per ct.

(5) *Lime.*—The total amount of lime in the products taken from each tree averages 0.95 pound, 83 per ct. of which is contained in the leaves and 15 per ct. in the wood.

(6) *Magnesia.*—The average amount of magnesia in the products removed from each tree is about 0.3 pound, 81 per ct. of which is present in the leaves, 9 per ct. in the fruit pulp and 8 per ct. in the new wood.

(7) *Relative proportions of constituents.*—Taking the total quantities of constituents given in Table II as an average, we have the following approximate relative proportions of the different constituents, based on 1 pound of nitrogen for comparison:

	Pounds.
Nitrogen	1.0
Phosphoric acid	0.25
Potash	1.0
Lime	1.5
Magnesia	0.5

(8) *Amounts or different constituents used by one peach tree.*—On the basis of the results presented above, each peach tree uses on an average the following approximate amounts of plant-food constituents during the growing season:

	Pounds.
Nitrogen	0.62
Phosphoric acid	0.15
Potash	0.60
Lime	0.95
Magnesia	0.30

PEAR TREES.

In the following table we give the results obtained with two varieties of pear trees, Kieffer and Angouleme, *Duchess de.* The Kieffer tree was 20 years old and the Duchess was 10 years old.

TABLE III.—PLANT FOOD USED IN ONE SEASON BY PEAR TREES.

VARIETY.	Part.	Weight.	WEIGHT.					
			Water.	Nitrogen.	Phos'ic acid (P_2O_5).	Potash (K_2O).	Lime (CaO).	Magnesia (MgO)
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Angouleme	Fruit	55.38	48.06	0.027	0.011	0.070	0.005	0.007
Kieffer	Fruit	267.38	230.06	0.123	0.044	0.267	0.032	0.037
Angouleme	Leaves	8.02	4.43	0.061	0.011	0.039	0.099	0.025
Kieffer	Leaves	38.63	24.22	0.248	0.038	0.139	0.413	0.094
Angouleme	New wood	3.25	1.80	0.011	0.004	0.011	0.031	0.005
Kieffer	New wood	9.75	5.56	0.025	0.009	0.022	0.058	0.014
Angouleme	Total weight	66.65	54.29	0.099	9.026	0.120	0.135	0.037
Kieffer	Total weight	315.76	259.84	0.396	0.091	0.428	0.503	0.145

The data embodied in the foregoing table can be summarized in the following statements:

(1) *Weight.*—The fruit constitutes about 65 per ct. of the weight of all the dry matter taken from the tree; the leaves form about 26.5 per ct. and the new wood, 8.5 per ct. of the water-

free products removed from the tree. The total weight of dry matter removed averages 68.28 pounds for each tree.

(2) *Nitrogen.*—The average amount of nitrogen taken from each tree is about 0.25 pound, of which 62 per ct. is in the leaves, 30.5 per ct. in the fruit and 7.5 per ct. in the new wood.

(3) *Phosphoric acid.*—The products taken from each tree contain on an average 0.06 pound of phosphoric acid, of which 46 per ct. is in the fruit, 42 per ct. in the leaves and 12 per ct. in the new wood.

(4) *Potash.*—The average amount of potash removed from each tree is 0.27 pound, 61 per ct. of which is in the fruit, 33 per ct. in the leaves and 6 per ct. in the new wood.

(5) *Lime.*—The products removed from each tree contain an average amount of 0.32 pound, of which 5.5 per ct. is in the fruit, 80.5 per ct. in the leaves and 14 per ct. in the new wood.

(6) *Magnesia.*—There is removed in the products taken from each tree 0.10 pound of magnesia, 66 per ct. of which is in the leaves, 24 per ct. in the fruit and 10 per ct. in the new wood.

(7) *Relative proportions of constituents.*—Taking the total quantities of constituents given in Table III as an average for each tree, we have the following approximate relative proportions of the different constituents, based on 1 pound of nitrogen for comparison:

	Pounds
Nitrogen	1.0
Phosphoric acid	0.25
Potash	1.0
Lime	1.3
Magnesia	0.5

(8) *Amounts of different constituents used by one pear tree.*—On the basis of the results presented above, each pear tree used on an average the following approximate amounts of plant-food constituents during one growing season:

	Pounds.
Nitrogen	0.25
Phosphoric acid	0.06
Potash	0.27
Lime	0.32
Magnesia	0.10

PLUM TREES.

In Table IV given below, we present the results obtained with two varieties of plum trees, Grand Duke and Italian Prune. The former was 9 years old; the latter 10 years.

TABLE IV.—PLANT FOOD USED IN ONE SEASON BY PLUM TREES.

VARIETY.	Part.	Weight.	WEIGHT.					
			Water.	Nitrogen.	Phos'ic acid (P_2O_5.)	Potash (K_2O).	Lime (CaO).	Magnesia (MgO)
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Grand Duke .	Fruit pulp.....	46.12	40.60	0.045	0.019	0.054	0.005	0.006
Italian Prune.	Fruit pulp.....	85.65	73.44	0.116	0.042	0.226	0.013	0.021
Grand Duke .	Stones.........	2.89	0.90	0.015	0.004	0.003	0.002	0.003
Italian Prune.	Stones.........	5.28	1.37	0.027	0.007	0.007	0.006	0.006
Grand Duke .	Stems..........	1.05	0.62	0.004	0.001	0.001	0.007	0.002
Italian Prune.	Stems..........	3.75	2.26	0.014	0.005	0.018	0.041	0.012
Grand Duke .	Leaves.........	9.94	6.07	0.069	0.017	0.043	0.210	0.064
Italian Prune.	Leaves.........	19.56	12.92	0.151	0.032	0.250	0.237	0.077
Grand Duke .	New wood......	2.50	1.24	0.013	0.005	0.006	0.046	0.008
Italian Prune.	New wood......	7.13	3.58	0.037	0.012	0.024	0.120	0.017
Grand Duke..	Total weight. ..	62.50	49.43	0.146	0.046	0.107	0.270	0.083
Italian Prune.	Total weight...	121.37	93.57	0.345	0.098	0.525	0.417	0.133

The data embodied in Table IV may be summarized in the following statements:

(1) *Weight.*—The total amount of dry matter removed from the trees in the form of fruit, foliage and new wood averages 20.44 pounds to a tree, of which 43.6 per ct. is found in the fruit pulp, 25.6 per ct. in the leaves, 14.4 per ct. in the plum stones, 11.7 per ct. in the new wood and 4.7 per ct. in the fruit stems.

(2) *Nitrogen.*—The average amount of nitrogen in the products taken from each tree is about 0.25 pound, distributed as follows: In the leaves, 44.8 per ct.; in the fruit pulp, 32.8 per ct.; in the new wood, 10.2 per ct.; in the fruit stones, 8.5 per ct.; in the fruit stems, 3.7 per ct.

(3) *Phosphoric Acid.*—In the products removed from each tree there is an average of 0.7 pound, of which 42.4 per ct. is found in the fruit pulp, 34 per ct. in the leaves, 11.8 per ct. in the new wood, 7.6 per ct. in the fruit stones, and 4.2 per ct. in the fruit stems.

(4) *Potash.*—The average amount of potash removed by the products of each tree is about 0.32 pound, distributed as follows: 46.4 per ct. in the leaves, 44.3 per ct. in the fruit pulp, 4.7 per ct. in the new wood, 3 per ct. in the fruit stems and 1.6 per ct. in the fruit stones.

(5) *Lime.*—Each tree loses on an average in the products removed 0.34 pound of lime, of which 65 per ct. is in the leaves, 2.6 per ct. in the fruit pulp, 24.3 per ct. in the new wood, 7 per ct. in the fruit stems and 1.1 per ct. in the fruit stones.

(6) *Magnesia.*—The total amount of magnesia removed per tree is 0.11 pound, 65.5 per ct. of which is in the leaves, 12 per ct. in the fruit pulp, 11.8 per ct. in the new wood, 6.5 per ct. in the fruit stems and 4.2 per ct. in the fruit stones.

(7) *Relative proportions of constituents.*—On the basis of the amounts of plant-food constituents given in Table IV, we have the following approximate relative proportions of the different constituents, taking one pound of nitrogen as a basis for comparison:

	Pounds
Nitrogen	1.0
Phosphoric acid	0.3
Potash	1.3
Lime	1.4
Magnesia	0.5

(8) *Amounts of different constituents used by one plum tree.*—On the basis of the data embodied in Table IV, each plum tree uses on an average the following approximate amounts of plant-food constituents during one growing season:

	Pounds.
Nitrogen	0.25
Phosphoric acid	0.07
Potash	0.31
Lime	0.34
Magnesia	0.11

QUINCE TREE.

Only one quince tree was used in our work, a Champion, 11 years old. The tabulated results of our work are given in Table V.

TABLE V.—PLANT FOOD USED IN ONE SEASON BY QUINCE TREE.

VARIETY.	Part.	Weight.	WEIGHT. Water.	Nitrogen.	Phos'ic acid (P_2O_5).	Potash (K_2O).	Lime (CaO).	Magnesia (MgO)
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Champion....	Fruit..........	77.00	63.41	0.092	0.042	0.185	0.014	0.025
	Leaves........	9.66	5.23	0.085	0.017	0.041	0.192	0.046
	New wood.....	2.69	1.39	0.013	0.005	0.011	0.067	0.008
	Total weight...	89.35	70.03	0.190	0.064	0.237	0.273	0.079

The following statements summarize the results obtained with the quince tree used in our work:

(1) *Weight.*—The total amount of dry matter removed from the tree in the form of fruit, foliage and new wood is 19.32 pounds, of which 70.3 per ct. is in the fruit, 22.9 per ct. in the leaves, and 6.8 per ct. in the new wood.

(2) *Nitrogen.*—The amount of nitrogen removed from the tree in the season's products is about 0.2 pound, of which nearly 50 per ct. is in the fruit, about 45 per ct. in the leaves and the rest in the new wood.

(3) *Phosphoric acid.*—The total amount of phosphoric acid taken from the tree in one season's products is 0.06 pound, 66 per ct. of which is in the fruit, 26 per ct. in the leaves, and 8 per ct. in the new wood.

(4) *Potash.*—About 0.25 pound of potash is removed in the products taken from the tree during one season, of which 78 per ct. is in the fruit, 17 per ct. in the foliage, and 5 per ct. in the new wood.

(5) *Lime.*—The total amount of lime found in the products of the tree is 0.27 pound, 50 per ct. of which is in the leaves, 25 per ct. in the new wood, and 5 per ct. in the fruit.

(6) *Magnesia.*—There is found 0.08 pound of magnesia in the products taken from the tree, 58 per ct. of which is in the leaves, 32 per ct. in the fruit and 10 per ct. in the new wood.

(7) *Relative proportions of constituents.*—On the basis of the amounts of plant-food constituents given in Table V, we have the following approximate relative proportions of the different constituents, taking 1 pound of nitrogen as a basis for comparison:

	Pounds.
Nitrogen	1.0
Phosphoric acid	0.33
Potash	1.25
Lime	1.45
Magnesia	0.40

(8) *Amounts of different constituents used by one plum tree.*—On the basis of the data embodied in Table V, the quince tree

used the following amounts of plant-food constituents during one growing season:

	Pound.
Nitrogen	0.19
Phosphoric acid	0.06
Potash	0.24
Lime	0.27
Magnesia	0.08

COMPARISON OF RESULTS OBTAINED WITH THE DIFFERENT VARIETIES.

Having considered for each variety of fruit tree the amount of plant-food constituents used in one season's growth of fruit, foliage and new wood, we will now compare the results given by the different varieties. We will consider these results (1) in respect to the total amount of plant-food constituents used on an average by each tree, (2) the relative proportions of plant-food constituents used and (3) the total amount used by the trees grown on one acre of land.

TOTAL AMOUNT OF PLANT-FOOD CONSTITUENTS USED.

The following table gives the average amount of nitrogen, phosphoric acid, potash, lime and magnesia used by each fruit tree of the different varieties studied:

TABLE VI.—PLANT FOOD USED BY ONE TREE OF DIFFERENT VARIETIES OF FRUIT TREES.

VARIETY.	Nitrogen.	Phosphoric acid (P_2O_5).	Potash (K_2O).	Lime (CaO).	Magnesia (MgO).
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Apple	1.47	0.39	1.57	1.62	0.66
Peach	0.62	0.15	0.60	0.95	0.29
Pear	0.25	0.06	0.27	0.32	0.09
Plum	0.25	0.07	0.32	0.34	0.11
Quince	0.19	0.06	0.24	0.27	0.08

These figures represent results obtained with trees in full vigor of growth and may be regarded as approaching as near average results as we can expect. Larger and older or smaller and younger trees could be selected which would give quite different results.

THE RELATIVE PROPORTIONS OF PLANT-FOOD CONSTITUENTS USED.

Using one pound of nitrogen as a basis for comparison, the relative amounts of other plant-food constituents are readily ascertained and these results are given for the different varieties of trees in the following table:

TABLE VII.—RELATIVE PROPORTIONS OF PLANT-FOOD CONSTITUTENTS USED.

VARIETY.	Nitrogen.	Phosphoric acid (P_2O_5).	Potash (K_2O).	Lime (CaO).	Magnesia (MgO).
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Apple	1	0.27	1.07	1.10	0.45
Peach	1	0.25	0.97	1.53	0.47
Pear	1	0.24	1.10	1.30	0.37
Plum	1	0.29	1.29	1.40	0.52
Quince	1	0.33	1.25	1.44	0.42
Average of all	1	0.27	1.14	1.35	0.45

The uniformity of the figures in this table is quite striking. It would appear from these data that the relative proportions of the different plant-food constituents are approximately the same for these different varieties of fruit trees. This means that, under like conditions of soil fertility, a mixture of nitrogen, phosphoric acid and potash which would meet the requirements of one variety would also meet the needs of the other varieties, so far as the supply of these plant-food constituents is concerned. What particular proportions are best adapted to meet the needs of any particular soil can be determined only by special experiment.

THE RELATIVE PROPORTIONS OF PLANT-FOOD CONSTITUENTS USED IN DIFFERENT PARTS OF TREE AND PRODUCTS.

It is a matter of interest and importance to notice the relative proportions of plant-food constituents used separately by the fruit, leaves and new wood.

TABLE VIII.—RELATIVE PROPORTIONS OF NITROGEN, ETC., IN DIFFERENT PARTS OF TREE.

PART OF TREE	Variety of fruit tree.	Nitrogen.	Phosphoric acid (P_2O_5).	Potash (K_2O).	Lime (CaO).	Magnesia (MgO.).
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Fruit	Apple	1.00	0.43	2.25	0.20	0.32
Fruit	Peach	1.00	0.49	2.05	0.12	0.23
Fruit	Pear	1.00	0.36	2.24	0.24	0.30
Fruit	Plum	1.00	0.35	1.43	0.13	0.18
Fruit	Quince	1.00	0.46	2.00	0.15	0.27
Fruit	Average	1.00	0.42	2.00	0.17	0.26

TABLE VIII.—RELATIVE PROPORTIONS OF NITROGEN, ETC., IN DIFFERENT PARTS OF TREE.—(*Continued.*)

PART OF TREE	Variety of fruit tree.	Nitrogen.	Phosphoric acid (P_2O_5)	Potash (K_2O).	Lime (CaO).	Magnesia (MgO).
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Leaves..........	Apple..........	1.00	0.16	0.31	1.64	0.54
Leaves..........	Peach..........	1.00	0.16	0.65	1.90	0.56
Leaves..........	Pear...........	1.00	0.16	0.58	1.66	0.40
Leaves..........	Plum...........	1.00	0.22	1.33	2.03	0.64
Leaves..........	Quince.........	1.00	0.20	0.50	2.26	0.54
Leaves..........	Average........	1.00	0.18	0.67	1.90	0.54
New wood.......	Apple..........	1.00	0.35	0.51	2.70	0.51
New wood.......	Peach..........	1.00	0.24	0.51	2.64	0.40
New wood.......	Pear...........	1.00	0.40	0.95	2.50	0.53
New wood.......	Plum...........	1.00	0.34	0.60	3.32	0.50
New wood.......	Quince.........	1.00	0.40	0.85	5.15	0.60
New wood.......	Average	1.00	0.35	0.68	3.26	0.51

A study of the data contained in Table VIII suggests the following statements:

(1) The relative amounts of phosphoric acid do not vary greatly in the different varieties of fruit, nor in the leaves of the different varieties of trees. There is somewhat more variation in the new wood of the different varieties of trees.

(2) The relative amounts of potash in the different fruits do not differ greatly, excepting only plums, in which the proportion of potash to nitrogen is less than in the other fruits, while in the leaves, the amount of potash, relative to nitrogen, is much higher than in any other variety. This peculiarity may not be characteristic of plums in general but only in the variety used or of the individual tree used.

(3) The chief fact in respect to lime that attracts attention is the large proportions present in the new wood of the plum and quince in comparison with the others.

AMOUNTS OF PLANT-FOOD CONSTITUENTS USED PER ACRE BY DIFFERENT VARIETIES OF FRUIT TREES.

Taking the figures given in Table VI and multiplying by the number of trees per acre, we obtain the total amounts of different plant-food constituents used in one season by the growth of fruit, foliage and new wood on one acre. The amount of plant-food used by the trees, branches and roots in increasing their size is not included in these results.

TABLE IX.—AMOUNTS OF PLANT FOOD USED PER ACRE.

VARIETY.	Number of trees an acre.	Nitrogen.	Phosphoric acid (P_2O_5).	Potash (K_2O.)	Lime (CaO.)	Magnesia (MgO).
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Apple	35	51.5	14.0	55.0	57.0	23.0
Peach	120	74.5	18.0	72.0	114.0	35.0
Pear	120	29.5	7.0	33.0	38.0	11.0
Plum	120	29.5	8.5	38.0	41.0	13.0
Quince	240	45.5	15.5	57.0	65.5	19.0

It is evident that the amounts of plant-foot constituents given in this table were present in the soil in available form during the growing season and within reach of the root systems of the trees. If one knew that there were no available plant-food in the soil, the above quantities would be the smallest amounts that one should apply for a season's growth. On the other hand, if one knew how much available plant-food were present in the soil, then it would simply be necessary to supplement this supply, if it were less than the season's requirements. At present we can ascertain what we want to know about the amount of available plant-food the soil can furnish only by rather crude experimenting.

It is quite noticeable from the figures given in Table IX that an acre of peach trees uses considerably larger quantities of plant-food than any of the other varieties of fruit trees given. The apple used approximately the same amounts per acre as the quince.

The amounts of nitrogen and potash used by any one kind of fruit trees were approximately the same in most cases while the amount of phosphoric acid was only about one-fourth the nitrogen or potash. In most commercial fertilizers used on fruit trees the phosphoric acid is present in proportions about four times the nitrogen. This is on the assumption that the soil contains more nitrogen relatively than phosphoric acid, which may or may not be true in individual cases. The question may be raised as to whether quantities of phosphoric acid are not frequently applied much in excess of the actual need of a season's crops.

AMOUNTS OF PLANT-FOOD CONSTITUENTS USED PER ACRE BY DIFFERENT PARTS OF TREE.

It is desirable to notice the amounts of plant-food constituents used per acre by different parts of fruit trees, since in some seasons no fruit is borne and under these conditions only the leaves

and new wood need be considered in respect to amounts of plant-food used.

TABLE X.—AMOUNTS OF NITROGEN, ETC., USED PER ACRE BY DIFFERENT PARTS OF TREE.

PART OF TREE	Variety of fruit tree.	Nitrogen.	Phosphoric acid (P_2O_5).	Potash (K_2O).	Lime (CaO).	Magnesia (MgO).
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Fruit	Apple	20.0	8.5	45.0	3.9	6.4
Fruit	Peach	17.5	8.6	36.0	2.2	4.1
Fruit	Pear	9.0	3.2	20.2	2.2	2.6
Fruit	Plum	13.3	4.7	18.5	4.4	3.0
Fruit	Quince	22.0	10.0	44.4	3.4	6.0
Fruit	Average	16.4	7.0	32.8	3.2	4.4
Leaves	Apple	30.3	4.8	9.5	49.7	16.3
Leaves	Peach	50.4	8.0	32.9	94.6	28.5
Leaves	Pear	18.5	3.0	10.7	30.7	7.2
Leaves	Plum	13.2	2.9	17.6	26.8	8.5
Leaves	Quince	20.4	4.1	9.8	46.1	11.0
Leaves	Average	26.6	4.6	16.1	49.6	14.3
New wood	Apple	1.1	0.4	0.6	3.0	0.6
New wood	Peach	6.6	1.6	3.4	17.4	2.6
New wood	Pear	2.2	0.8	2.0	5.4	1.1
New wood	Plum	3.0	1.0	1.8	10.0	1.5
New wood	Quince	3.1	1.2	2.6	16.1	1.9
New wood	Average	3.2	1.0	2.1	10.4	1.5

From the data in Table X, we gather the following statements:

(1) In respect to the amounts of plant-food used per acre by the fruit of the different varieties of trees, the amounts of nitrogen, phosphoric acid and potash in the different fruits are in about the following order: Quinces use the most, and then follow apples, peaches, plums and pears.

(2) Potash is present in the fruit in larger quantities than is any other plant-food constituent; nitrogen comes second, being present to the extent approximately, of one-half the amount of potash. Then follow, in order, phosphoric acid, magnesia and lime, all of these being present in much smaller amounts.

(3) In the leaves, the plant-food constituents used per acre are greatest in the case of the peach, the apple coming second and then quince, pear and plum.

(4) Lime is present in the leaves and also in the new wood in much larger quantities than any other plant-food constituents; nitrogen comes second, followed in order by potash, magnesia and phosphoric acid.

(5) In the new wood, the plant-food constituents used per acre are greatest in the case of the peach trees after which come in order quince, plum, pear and apple.

PART II. TABULATED ANALYSIS SHOWING AMOUNTS OF PLANT-FOOD CONSTITUENTS IN FRUITS, VEGETABLES, ETC.

For some years past many data have been accumulated by the Station in making analyses of a large variety of plant materials. It has seemed desirable to bring these results together and publish them as matters of interest and for reference.

TABULATED ANALYSES OF FRUITS, VEGETABLES, ETC.

FRUITS.	Moisture.	Nitrogen.	Phosphoric acid.	Potash.
APPLES.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Baldwin (1) —fruit..........	84.84	.062	.021	.106
leaves........	57.06	.494	.073	.480
wood.........	50.03	.465	.120	.260
(2) fruit..........	85.64	.040	.018	.100
leaves........	37.83	1.15	.173	.269
wood.........	51.78	.450	.160	.227
Golden Sweet —flesh..........	86.86	.050	.017	.098
skin..........	83.44	.076	.025	.171
core..........	85.48	.151	.045	.174
leaves........	56.60	.456	.065	.243
wood.........	49.57	.485	.151	.273
R. I. Greening (1) —fruit..........	84.13	.043	.010	.094
leaves........	62.55	.734	.090	.543
wood.........	48.74	.385	.113	.282
(2) fruit..........	86.74	.044	.018	.092
leaves........	48.34	1.000	.169	.403
wood.........	52.87	.452	.158	.229
Hubbardston —fruit..........	82.35	.067	.018	.109
leaves........	54.76	.569	.068	.253
wood.........	49.06	.459	.133	.250
Tompkins King —fruit..........	83.44	.043	.025	.177
leaves........	60.07	.483	.052	.387
wood.........	52.66	.317	.095	.274
Northern Spy —fruit..........	84.08	.027	.022	.137
leaves........	56.32	.942	.109	.292
wood.........	46.88	.377	.143	.260
Red Astrachan —flesh..........	89.74	.048	.013	.084
skin..........	85.81	.114	.048	.207
core..........	85.71	.201	.056	.129
leaves	53.00	.761	.117	.597
wood.........	49.40	.572	.177	.324
Twenty Ounce —fruit..........	84.93	.042	.020	.100
leaves........	59.00	.472	.062	.131
wood.........	49.42	.516	.191	.212
Yellow Transparent—flesh..........	88.16	.047	.020	.103
skin..........	85.34	.057	.038	.152
core..........	85.63	.134	.040	.121
leaves........	48.60	.504	.077	.170
wood.........	49.33	.451	.172	.182
BLACKBERRIES.				
Fruitland—berry..................	85.10	.216	.058	.231
leaves..................	48.14	1.04	.12	.77
new wood..............	38.15	.55	.15	.26
old wood...............	38.26	.27	.025	.15

TABULATED ANALYSES, ETC.—*Continued.*

FRUITS.	Moisture.	Nitrogen.	Phosphoric acid.	Potash.
CHERRIES.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Kentish—flesh	89.98	.165	.044	.202
stones	46.81	.468	.154	.255
stems	68.76	.356	.133	.609
leaves	65.10	.590	.110	.720
wood	49.51	.440	.150	.300
CURRANTS.				
Champion (black)—berries	82.84	.549	.137	.359
stems	75.71	.284	....	.939
leaves	64.66	.703	.456	1.05
new wood	55.33	.411	.232	.429
old wood	50.10	.449	.220	.299
London (red) —berries	87.13	.278	.116	.288
stems	75.18	1.01	.372	.732
leaves	65.97	.710	.210	.930
new wood	50.36	.452	.218	.328
old wood	45.74	.570	.230	.220
(white) —berries	84.26	.294	.129	.375
stems	73.94	.474	.190	1.08
leaves	65.78	.619	.212	.722
new wood	53.97	.391	.189	.331
old wood	48.21	.550	.228	.231
DEWBERRIES	88.60	.219	.056	.203
GOOSEBERRIES.				
Downing—berries	89.42	.156	.079	.026
leaves	66.25	.71	.230	1.13
new wood	44.20	.40	.210	.42
old wood	39.77	.52	.250	.39
GRAPES.				
Catawba —berries	78.59	.163	.090	.349
leaves	72.63	.449	.090	.301
new wood	56.69	.269	.087	.282
Concord —berries	80.01	.116	.070	.336
leaves	71.49	.533	.088	.462
new wood	53.60	.288	.079	.306
Delaware —berries	80.19	.202	.099	.420
leaves	72.58	.422	.088	.269
new wood	52.94	.301	.099	.278
Diamond —berries	79.29	.174	.064	.282
leaves	78.44	.330	.080	.230
new wood	72.27	.304	.086	.242
Niagara —berries	78.44	.151	.067	.261
leaves	69.00	.691	.130	.536
new wood	54.33	.324	.096	.429
Worden —berries	81.13	.176	.045	.253
leaves	69.71	.385	.055	.221
new wood	46.50	.326	.080	.241
PEACHES.				
Champion—flesh	89 31	.096	.035	.208
stones	39.93	.219	.055	.094
leaves	64.45	.946	.150	.803
new wood	53.45	.454	.099	.239
Elberta —flesh	88 78	.059	.041	.150
stones	32.67	.254	.081	.067
leaves	63.78	.779	.141	.304
new wood	49.52	.431	.121	.222
Hills Chili—flesh	86.94	.076	.041	.197
stones	29.84	.328	.083	.076
leaves	65.33	.995	.149	.631
new wood	62.76	.406	.102	.197
PEARS.				
Doyenne Boussock —flesh	86.07	.050	.021	.156
skin	78.32	.072	.015	.145
core	83.62	.079	.034	.164
leaves	38.20	.451	.049	.482
new wood	50.33	.417	.129	.288

TABULATED ANALYSES, ETC.—*Continued.*

FRUITS.	Moisture.	Nitrogen.	Phosphoric acid.	Potash.
PEARS—(*Continued*).	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Angouleme, Duchess de—fruit	86.78	.048	.019	.126
leaves	55.23	.761	.143	.484
wood	55.53	.328	.118	.329
Kieffer —fruit	86.38	.046	.016	.100
leaves	62.70	.642	.099	.361
new wood	57.04	.259	.092	.226
PLUMS.				
Grand Duke —flesh	88.06	.100	.042	.117
stones	32.83	.525	.152	.097
stems	59.52	.349	.117	.102
leaves	61.10	.692	.175	.436
new wood	49.59	.509	.192	.233
Italian prune—flesh	85.74	.135	.050	.264
stones	26.00	.512	.135	.135
stems	60.40	.386	.137	.475
leaves	66.06	.770	.164	1.28
new wood	50.20	.523	.162	.338
QUINCES.				
Champion—fruit	82.35	.119	.054	.240
leaves	54.15	.885	.173	.422
new wood	51.57	.494	.204	.391
RASPBERRIES.				
Columbian (purple) —fruit	83.20	.188	.090	.23
leaves	40.64	1.40	.250	.69
new wood	43.03	.44	.120	.25
old wood	37.00	.21	.032	.21
Cuthbert (red) —fruit	84.35	.207	.088	.24
leaves	33.28	1.58	.280	.68
new wood	41.33	.39	.150	.23
old wood	33.52	.33	.080	.19
Golden Queen (yellow)—fruit	84.55	.179	.083	.22
leaves	29.42	1.53	.31	.628
new wood	34.70	.47	.15	.215
old wood	17.43	.41	.09	.27
Mills No. 15 (black) —fruit	80.80	.265	.111	.351
leaves	58.94	.900	.221	.500
new wood	41.72	.540	.120	.270
old wood	36.70	.230	.032	.300
STRAWBERRIES.				
Bederwood —berries	90.89	.149	.030	.254
hulls	79.57	.355	.086	.406
Bubach —berries	91.53	.121	.059	.219
hulls	82.22	.292	.066	.437
Crescent —berries	90.23	.154	.067	.277
hulls	80.81	.282	.067	.391
Gandy —berries	89.30	.133	.065	.246
hulls	81.83	.229	.065	.403
Sadie —berries	91.51	.114	.056	.215
hulls	86.66	.209	.048	.306
Sharpless —berries	90.27	.113	.057	.186
hulls	82.42	.246	.114	.376
Tennessee Prolific—berries	91.15	.117	.058	.207
hulls	82.07	.283	.116	.317

TABULATED ANALYSES, ETC.—*Continued.*

GARDEN VEGETABLES.		Moisture.	Nitrogen.	Phosphoric acid.	Potash.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct*
Asparagus	—tops: May 5	93.71	.350	.112	.252
	August 18	71.59	.378	.122	.730
	berries	55.33	1.09	.339	.835
Beans (string)	—pods and beans	92.33	.249	.076	.291
	leaves	84.22	.529	.099	.519
	stalks	83.97	.389	.101	.529
Beets:					
Egyptian	—root	89.00	.299	.053	.458
	top	86.20	.500	.087	.669
Red-turnip	—root	91.64	.298	.068	.758
	top	89.88	.224	.091	.519
	young tops and roots	91.11	.368	.091	.642
Sugar	—(pulp)	86.70	.205	.029	.105
Cabbages	—head	90.10	.317	.090	.336
	stump and outside leaves	86.60	.366	.098	.427
Carrots	—roots	88.70	.231	.129	.529
	leaves	79.60	.537	.129	.109
Cauliflower	—head	93.10	.279	.081	.326
	leaves	90.20	.363	.084	.470
Cucumbers	—edible part	96.11	.110	.055	.210
	leaves	86.35	.416	.079	.710
	vines	90.79	.201	.080	.578
Egg-plant	—edible part	93.10	.188	.050	.277
	leaves	71.90	.863	.138	.981
Lettuce:					
Deacon		94.00	.224	.076	.448
	garden-grown	96.22	.164	.048	.368
	greenhouse-grown	93.27	.250	.061	.731
Mushrooms:					
	greenhouse-grown	86.82	1.11	.386	.683
Muskmelons	—fruit	93.30	.215	.081	.412
	vines and leaves	87.10	.348	.083	.602
Onions:					
Yellow Danvers	—bulb	88.10	.225	.086	.217
	top	88.90	.296	.056	.535
Parsnips	—root	77.70	.219	.178	.662
	top	82.50	.420	.138	.108
Peas (garden)	—green	74.16	1.14	.279	.426
	pods	87.47	.234	.044	.212
	leaves	85.59	.557	.070	.487
	vines	81.08	.227	.047	.721
Pumpkins	—flesh	89.10	.155	.066	.261
	vines and leaves	88.10	.415	.096	.570
	seeds	79.40	.867	.499	.433
Radishes:					
Red	—garden-grown root	95.73	.144	.051	.344
	garden-grown top	92.07	.424	.069	.415
	greenhouse-grown root	95.38	.130	.0577	.339
	greenhouse-grown top	90.80	.420	.05	.484
White	—garden-grown-root	95.40	.158	.064	.426
	garden-grown top	92.26	.413	.062	.416
Rhubarb:					
No. 1	—stems	96.85	.101	.043	.372
	leaves	92 89	.366	.091	.528
No. 18	—stems	96.31	.091	.043	.326
	leaves	93.47	.260	.072	.473
Salsify	—root	77.60	.477	.162	.522
	top	84.90	.500	.106	1.10
Sweet corn	—corn	73.72	.662	.276	.336
	husks	85.20	.206	.096	.335
	cob	74.88	.196	.101	.264
	leaves	84.26	.398	.112	.543
	stalks	84.94	.172	.056	.553
Tomatoes (1)	—fruit	94.12	.150	.070	.318
	leaves	90.70	.337	.111	.388
	stalks	90.11	.347	.092	.513
(2)	—fruit	94.80	.203	.059	.345
	leaves and stalks	85.50	.428	.052	.580
Turnips:					
Flat	—root	91.20	.280	.124	.480
	top	87.70	.370	.109	.649

TABULATED ANALYSES, ETC.—*Continued.*

GARDEN VEGETABLES.	Moisture.	Nitrogen.	Phosphoric acid.	Potash.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
Yellow Swedish—root	90.90	.242	.104	.414
top	89.30	.420	.127	.496
Watermelons —fruit	92.90	.167	.055	.306
vines and leaves	84.50	.501	.074	.496
MISCELLANEOUS PLANTS. (Stems and leaves.)				
Balm	64.07	.507	.194	.722
Dandelion	88.79	.341	.091	.573
Endive	92.26	.299	.066	.756
Horehound	78.77	.711	.140	.964
Hyssop	76.51	.507	.157	.538
Peppermint (garden)	75.92	.337	.210	.657
Peppermint (wild)	76.00	.434	.170	.542
Pot marjoram	66.61	.488	.164	.581
Prickly Comfrey	90.75	.331	.150	.632
ROSE BUSHES AND FOLIAGE. (Partly air-dried.)				
American Beauty—flowers	81.30	.507	.112	.482
leaves	55.60	1.40	.333	1.30
wood	53.60	.534	.283	.520
Bridesmaid —flowers	83.50	.276	1.27	.419
leaves	69.20	.788	.203	.949
wood	57.30	.547	.273	.440
The Bride —flowers	79.00	.391	.139	.575
leaves	66.00	.877	.194	1.04
wood	58.60	.443	.236	.451
Rue	78.08	.559	.156	.668
Sage	84.45	.538	.106	.605
Tansy (garden)	77.47	.523	.149	.732
Tarragon	78.03	.556	.158	.756
Thyme (French)	71.32	.402	.152	.648
Winter Savory	71.86	.529	.189	.695
Wormwood	72.50	.696	.223	.852

APPENDIX.

I. Periodicals Received by the Station.

II. Meteorological Records.

Appendix.

PERIODICALS RECEIVED BY THE STATION.

Acclimitation	Complimentary.
Acker und Gartenbau Zeitung	"
Agricultural Epitomist	"
Agricultural Gazette of New South Wales	"
Agricultural Journal and Mining Record (Natal)	"
Agricultural Journal of the Cape of Good Hope	"
Agricultural Ledger	"
Agricultural News	"
Allegan Gazette	"
American Agriculturist	Subscription.
American Chemical Journal	"
American Chemical Society, Journal	"
American Cultivator	Complimentary.
American Entomological Society, Transactions	Subscription.
American Fancier	"
American Fertilizer	"
American Florist	"
American Grange Bulletin	Complimentary.
American Grocer	"
American Hay, Flour and Feed Journal	"
American Journal of Physiology	Subscription.
American Naturalist	"
American Philosophical Society, Proceedings	Complimentary.
American Poultry Journal	"
American Stock Keeper	"
Analyst	Subscription.
Annales de l'Institut Pasteur	"
Annals and Magazine and Natural History	"
Annals of Botany	"
Archiv der gesammte Physiologie (Pflueger)	"
Archiv fuer Hgyiene	"
Association Belge des Chimistes, Bulletin	Complimentary.
Australian Garden and Field	"
Beet Sugar Gazette	"

Beiträge zur Chemischen Physiologie und Pathologie	Subscription.
Berichte der deutschen botanischen Gesellschaft....	"
Berichte der deutschen chemischen Gesellschaft.....	"
Bibliographia Agronomica Universalis............	"
Biochemisches Centralblatt....................	"
Biological Bulletin...........................	"
Biologisches Centralblatt.....................	"
Boletim da Agricultura........................	Complimentary.
Boston Society of Natural History, Proceedings.....	Subscription.
Botanical Gazette.............................	"
Botanische Zeitung............................	"
Botanisches Centralblatt......................	"
Botaniste, Le.................................	"
Breeders' Gazette.............................	"
Buffalo Society of Natural Sciences, Bulletin........	Complimentary.
Bulletin of the Department of Agriculture, Jamaica.	"
Caledonia Era.................................	"
California Fruit Grower.......................	Subscription.
Canadian Entomologist.........................	"
Canadian Horticulturist.......................	Complimentary.
Centralblatt fuer Agrikultur-Chemie..............	Subscription.
Centralblatt fuer Bakteriologie und Parasitenkunde.	"
Chemical News.................................	"
Chemical Society, Journal.....................	"
Chemiker Zeitung..............................	"
Chemisches Centralblatt.......................	"
Chicago Daily Drovers' Journal.................	Complimentary.
Chicago Dairy Produce.........................	"
Cincinnati Society of Natural History, Journal.....	"
Columbus Horticultural Society, Journal............	"
Commercial Poultry............................	"
Country Gentleman.............................	Subscription.
Country World.................................	Complimentary.
Dairy and Creamery............................	"
Dairy and Produce Review......................	"
Detroit Free Press............................	"
Elgin Dairy Report............................	"
Elisha Mitchell Scientific Society, Journal.........	"
English Catalogue of Books....................	"
Entomological News............................	Subscription.
Entomological Society of Washington, Proceedings.	"
Entomologische Zeitschrift....................	"

Entomologist	Subscription.
Entomologists' Record	"
Fanciers' Review	Complimentary.
Farm and Fireside	"
Farm and Live Stock Journal	"
Farm Journal	"
Farm Life	"
Farm News	"
Farm Poultry Semi-Monthly	"
Farm, Stock and Home	"
Farmers' Advocate	"
Farmers' Call	"
Farmers' Guide	"
Farmers' Progress	"
Farmers' Sentinel	"
Farmers' Tribune	"
Farmers' Visitor	"
Farmers' Voice	"
Feather	Subscription.
Feathered World	"
Floral Life	"
Florists' Exchange	"
Flour and Feed	Complimentary.
Fruit Grower	"
Fuehling's Landwirtschaftliche Zeitung	Subscription.
Garden	"
Garden Magazine	"
Gardeners' Chronicle	"
Gardening	"
Gartenwelt	"
Gleanings in Bee Culture	Complimentary.
Green's Fruit Grower	"
Hartwick Seminary Monthly	"
Hedwigia	Subscription.
Herd Register	Complimentary.
Hoard's Dairyman	"
Holstein-Friesian Register	"
Holstein-Friesian World	"
Homestead	"
Horticulture	Subscription.
Horticultural Visitor	Complimentary.
Hygienische Rundschau	Subscription.

Indiana Farmer	Complimentary.
Insect World	"
Ithaca Democrat	"
Jahresbericht der Agrikultur-Chemie	Subscription.
Jahresbericht Gärungs-Organismen	"
Jahresbericht der Nahrungs und Genuss mittel	"
Jahresbericht Pflanzenkrankheiten	"
Jahresbericht der Tier-Chemie	"
Jersey Bulletin	Complimentary.
Journal of Agricultural Science	Subscription.
Journal of Agriculture, Victoria	Complimentary.
Journal of Biological Chemistry	Subscription.
Journal de Botanique	"
Journal of the Department of Agriculture of Western Australia	Complimentary.
Journal of Experimental Medicine	Subscription.
Journal of Experimental Zoology	"
Journal fuer Landwirtschaft	"
Journal of Mycology	"
Journal of Physiology	"
Just's Botanischer Jahresbericht	"
Kimball's Dairy Farmer	Complimentary.
Landwirtschaftlicher Jahrbuch	Subscription.
Landwirtschaftlicher Jahrbuch der Schweiz	"
Landwirtschaftlichen Versuchs-Stationen	"
Live Stock and Dairy Journal	Complimentary.
Live Stock Report	"
Metropolitan and Rural Home	"
Michigan Farmer	"
Milch Zeitung	Subscription.
Milchwirtschaftliches Zentralblatt	"
Mirror and Farmer	Complimentary.
Monthly Weather Review	"
National Nurseryman	"
National Farmer and Stock Grower	"
National Stockman and Farmer	"
Naturaliste Canadienne	"
Nebraska Farmer	"
New England Farmer	"
New York Academy of Science, Annals and Transactions	Subscription.
New York Botanical Garden, Bulletin	Complimentary.

New York Entomological Society, Journal	Subscription.
New York Farmer	Complimentary.
New York Fruit and Produce Review	"
New York Tribune Farmer	"
North American Horticulturist	"
Northwest Pacific Farmer	"
Ohio Farmer	"
Ohio Poultry Journal	Subscription.
Pacific Coast Fanciers' Monthly	"
Pacific Fruit World	Complimentary.
Pacific Rural Press	Subscription.
Photo-Miniature	"
Photographic Times-Bulletin	"
Popular Agriculturist	Complimentary.
Poultry Herald	Subscription.
Poultry Keeper	Complimentary.
Poultry Industry	"
Poultry Monthly	"
Practical Poultryman and Poultry Star	"
Practical Farmer	"
Practical Fruit-Grower	"
Praktische Blätter fuer Pflanzenschutz	Subscription.
Psyche	"
Queensland Agricultural Journal	Complimentary.
Rabenhorst's Kryptogamen-Flora	Subscription.
Reliable Poultry Journal	"
Republic	"
Revue Generale de Botanique	"
Revue Generale du Lait	"
Revue Horticole	"
Revue Mycologique	"
Royal Agricultural Society, Journal	"
Royal Horticultural Society, Journal	"
Rural New Yorker	"
Salt Lake Herald	Complimentary.
Saint Louis Academy of Science, Transactions	"
Sanitary Inspector	"
Science	Subscription.
Scientific Roll, Bacteria	"
Society of Chemical Industry, Journal	"
Societe Entomologique de France, Bulletin	Complimentary.
Societe Mycologique de France, Bulletin	Subscription.

Southern Planter	Complimentary.
Southern Tobacconist and Modern Farmer	"
Southern Farm Magazine	"
Southwestern Farmer and American Horticulturist	"
Station, Farm and Dairy	"
Stazione Sperimentale Agrarie Italiane	"
Successful Farming	"
Sugar Beet	"
Texas Stockman and Farmer	"
Torrey Botanical Club, Bulletins and Memoirs	Subscription.
Transvaal Agricultural Journal	Complimentary.
Up-to-Date Farming and Gardening	"
Utica Semi-Weekly Press	"
Wallace's Farmer	"
West Indian Bulletin	"
West Virginia Farm Review	"
Western Fruit-Grower	"
Western Plowman	"
Woman's Home Companion	"
Zeitschrift fuer Analytische Chemie	Subscription.
Zeitschrift fuer Biologie	"
Zeitschrift fuer Entomologie	Complimentary.
Zeitschrift fuer Fleisch und Milch Hygiene	Subscription.
Zeitschrift fuer Hygiene und Infektions Krankheiten	"
Zeitschrift fuer Pflanzenkrankheiten	"
Zeitschrift fuer Physiologische Chemie	"
Zeitschrift fuer Untersuchung der Nahrungs und Genussmittel	"
Zoological Record	"
Zoologischer Anzeiger	"

METEOROLOGICAL RECORDS FOR 1905.

PRECIPITATION BY MONTHS SINCE 1882.

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1882	....	....	....	....	...	3.69	2.42	2.37	1.25	0.62	1.22	0.55	....
1883	0.48	1.44	0.88	1.58	4.45	4.12	2.98	3.47	2.12	2.10	1.54	0.73	25.89
1884	1.83	2.01	2.54	0.83	2.49	2.01	2.33	1.44	3.17	1.67	1.01	0.97	22.30
1885	1.07	0.61	0.12	1.26	1.58	2.49	4.64	5.02	2.11	2.88	1.36	0.76	23.90
1886	1.13	0.95	1.13	4.13	1.92	2.92	4.41	2.86	2.31	1.39	3.48	1.24	27.87
1887	0.18	2.17	0.48	1.37	0.46	2.01	6.37	3.03	0.75	1.74	1.68	1.35	22.29
1888	0.78	1.04	1.43	3.09	2.79	3.88	0.99+	4.02	2.73	3.47	2.02	1.24+	27.48
1889	2.99+	0.25	0.66+	3.28	1.21	7.47	4.57	4.98	2.50	3.32	3.44	1.62	32.28
1890	2.16	1.45	2.16	2.20	5.49	5.26	1.07	4.34	5.81	4.54	2.40	....	36.88
1891	1.44	1.57	3.25	1.63	0.49	4.31	3.52	3.16	0.47	3.65	0.74	3.29	27.52
1892	0.57	0.88	0.55	0.67	4.04	3.95	1.89	4.77	1.12	1.34	2.67	0.72	23.17
1893	1.62	3.71	1.94	2.59	4.92	3.08	3.68	5.38	2.68	1.59	1.09	1.56	33.84
1894	2.21	2.71	1.36	2.43	7.03	1.77	1.50	1.22	4.64	3.59	0.43	0.47	29.36
1895	0.96	....	0.29	1.33	2.88	....	....	2.66	0.94	0.72	2.31	2.49	.....
1896	1.19	2.28	0.84	0.41	2.31	3.71	4.12	3.33	4.27	2.26	2.18	0.71	27.61
1897	0.64	0.21	2.12	1.90	2.19	3.16	5.28	1.27	2.36	0.73	2.53	1.39	23.78
1898	1.74	0.83	1.54	2.03	1.90	2.39	1.32	3.60	1.86	3.83	2.03	0.33	22.90
1899	0.37	0.30	1.22	1.12	1.69	1.71	4.15	1.05	2.23	2.69	1.36	1.46	19.35
1900	1.43	2.42	0.02	0.95	1.71	1.45	6.53	1.75	0.91	3.65	6.13	0.78	27.73
1901	0.72	....	2.19	4.43	3.80	2.07	3.97	5.62	2.46	1.35	2.09	3.37	32.07
1902	0.86	0.66	1.94	1.92	2.84	4.33	5.25	2.41	2.88	2.32	0.74	0.74	26.89
1903	1.81	1.11	5.60	2.60	0.23	7.77	4.86	7.21	1.30	4.19	1.63	0.38	38.69
1904	0.80	1.03	2.41	1.67	4.04	3.37	5.73	2.56	3.26	2.06	0.26	1.42	28.61
1905	0.40	0.27	1.09	2.05	2.01	8.78	3.59	5.44	1.90	3.69	1.32	1.84	32.38

AVERAGE MONTHLY TEMPERATURE SINCE 1882.

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1883	17.4	22.3	23.6	43.3	52.0	66.6	67.4	65.6	56.3	46.6	39.1	27.5
1884	17.6	28.3	29.5	40.7	54.3	67.1	66.5	69.9	65.2	50.5	36.5	27.2
1885	20.6	11.4	18.8	41.2	54.3	63.6	69.7	65.0	58.3	49.2	39.3	27.8
1886	19.6	22.9	30.2	48.1	55.7	64.0	68.0	67.5	61.8	49.6	36.8	22.2
1887	20.2	23.2	26.3	41.1	62.5	65.7	75.6	66.5	57.7	47.0	37.6	27.6
1888	16.4	22.8	24.6	40.8	54.3	66.5	66.8	68.0	62.2	43.9	39.4	29.3
1889	29.1	18.1	33.9	45.1	58.4	65.3	70.2	66.0	60.5	44.0	40.3	35.2
1890	31.2	30.9	28.8	44.2	52.3	67.1	69.5	67.7	60.1	49.3	37.6	21.4
1891	25.9	28.3	30.8	45.3	52.0	66.4	66.4	68.5	66.2	48.3	38.4	35.5
1892	21.4	25.9	26.5	43.5	52.8	68.6	70.2	69.4	61.3	50.0	35.9	25.2
1893	15.5	20.6	29.5	41.1	54.1	68.2	69.8	68.8	58.0	52.0	38.2	27.5
1894	29.7	20.9	38.9	44.1	55.5	67.8	74.2	66.8	64.8	52.7	36.0	31.5
1895	21.8	16.9	26.9	44.4	59.0	....	....	71.2	61.7	45.4	39.6	31.4
1896	22.4	24.1	24.4	49.3	62.0	65.9	71.4	70.0	60.2	56.5	42.9	27.1
1897	23.2	26.1	33.8	45.0	55.4	62.3	73.6	67.6	62.3	52.6	39.7	29.2
1898	26.2	26.8	....	43.2	57.0	67.7	74.2	71.0	65.9	52.1	37.9	27.9
1899	22.1	20.4	30.4	46.6	57.6	69.5	71.2	71.6	60.6	53.4	38.9	30.0
1900	26.0	22.6	23.6	43.5	56.7	68.4	72.6	74.1	66.1	57.9	41.1	28.7
1901	26.1	18.5	32.2	46.5	56.9	68.9	76.6	71.0	64.0	51.4	34.3	27.7
1902	23.2	22.2	39.5	46.6	56.1	63.2	71.2	67.6	63.6	43.1	46.3	25.7
1903	25.7	28.1	42.4	45.9	60.4	63.2	70.8	65.5	64.4	52.5	36.2	23.3
1904	18.9	23.1	30.9	41.4	60.3	67.8	70.0	68.2	61.9	48.4	36.9	22.5
1905	19.8	18.9	33.1	44.8	57.5	66.4	71.8	68.7	63.7	52.4	37.6	32.0

Readings of the Standard Air Thermometer.

Date.	January. 7 A. M.	January. 12 M.	January. 5 P. M.	February. 7 A. M.	February. 12 M.	February. 5 P. M.	March. 7 A M.	March. 12 M.	March. 5 P. M.	April. 7 A. M.	April. 12 M.	April. 5 P. M.	May. 7 A. M.	May. 12 M.	May. 5 P. M.	June. 7 A. M.	June. 12 M.	June. 5 P. M.
1	41	46	43	11.5	21.5	22	11	23	22	34	45	41	35	42	45	55	71	69
2	42	37	32.5	4	10	6.5	12	26	26	31	42	40	40	41	50	55	68	57
3	13	11	10	5	5	7	23.5	30	33.5	30	45	55	61	79	80	52	63	69.5
4	5	9.5	5	7	11	9	25	18	18	46	62	57	45	63.5	70	53	64	66
5	13	13	12	—4	16	11	7	24	28	43	52	48	51	65	55	59	70	76
6	24	30	28	23	27	23	16	23	22	33	40	39	57	70	65	56	59	59
7	32	26	26	10	11.5	13	16	31	35	33	41	38	57	59	68	57	55	55.5
8	22	22	22	—3	15	11.5	31	30	29	32	36	41	50	65	74	48	59	68.5
9	18	20	23	25	32.5	36	18	36.5	38	40	58	58	42	50	50	56	73	79
10	14	18	16	24	26	21	30	25	26	52	61	51	46.5	59	57	65	70	68
11	15	19	16.5	10	16	16	14	26	29	43	44	41.5	51	64	68	64	71	71
12	37	41	37	20	24	29	12	27	27	35	46	50	59	67	78	65	73.5	75
13	16	17	15	17	17	6	12	25	25	38	60	59	56.5	67	71	65	71.5	75
14	7	13	5	—5	8	13	11	28	23.5	35	40	31	59	65	67	66	79	81
15	15	15	13	11	14	9	5	28	32	32	43	34	70	66	67	66	83	83
16	18	23	20	0	13	20.5	19	28	24	29	34	38	53	64	61	70	82	72
17	24	25	24	24	28	27	23	35	43	30	30	36	59	66	68	70	83	70
18	26	31	31	11	16	13	44	50	50	31	35	33	54	57	53	73	82	73
19	39	37	35	5	26	24	35	31	28	33	51	54	51	61.5	57	70	83	75
20	27.5	31	28	27	35.5	44	27	27.5	28	47.5	59	54	42	47	53	74	85	87
21	27	31	27	31	35	35	32	33	32	43	39	32	47	60	63	67	71	71
22	21	24	20	32	31	29	30	40	39	34	48	47	51	62	56	68	75	73.5
23	11	15	13	27	32	29	36	44	44	40	51	50	44	54	58	55	66	67
24	14	20	22	18	33	34	42	47	42	36	53	58	50	68	72	59	73	78
25	12	9	8	15	33	36	39	52	51.5	41	53	61	58	77	75	69	78	78
26	—1	5	5	27	31	21	35	56	56	46	63	64	66	66	65	72	56	60
27	18	21	23	16	23.5	30	43	55	55	52	63	60	53	65.5	65	56	61	65
28	16	17	13	30	30	25	38	63	73	45	70	75	56	70	71	57	70	74
29	5	7	5	......	......	......	53	76	77	53	60	63	57	70	53	63	75	77
30	12	21	15	......	......	......	60	55	50	52	59	51	53	65	65	64	78	79
31	9	20	18	......	......	......	39	62	54	......	......	......	56	68	65	......	......	......
Averages	19.1	21.8	19.7	14.9	22.2	21.4	27.1	37.3	37.4	39	49.4	48.6	52.6	62.7	63.4	62.3	71.6	71.7

READINGS OF THE STANDARD AIR THERMOMETER—(*Concluded*).

DATE.	JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.		
	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.
1	68	76	76	58	65	71	58	67	70	56	78	81	42	37	31	9	24	24.5
2	60	75	71	62	73	74	60	72	67	63	76.5	69	31	40	38	31	36	40
3	65	78	83.5	61.5	74	75	67	77	75	55	71.5	71	36	42	40.5	33	34	33
4	70	81	80	63	78	84	63	76	69	60	74	75.5	38	42	42	24	25	22
5	70	75	72	67	81.5	83.5	56	64	67	62	68	64	33	47	44	24	28	26
6	72	83	83	69	78	81	59	65	70	45	59	56	44	51	42	29	34	36
7	73	77	78	68	79	80	59	70	71	43	60	63	39	43	40	36	43	38
8	73	83.5	80	68	79	80	60	71	71	46	71	73	36	43	35	35	43	37
9	73	83	79	65	82.5	84	55	75	75	58	76	73	31	39	34	35	40	39
10	70	76	80	74	88.5	84	62	73	72	53	70	70	32	40	35	33	24	22
11	69	86	84	73	73	72	63	64	61	56	58	45	38	50	49	32	35	34.5
12	75	85	73	73	83.5	83	58	65	71	42	50	47	44	56	56	34	40	38
13	72	81	66	73	78	73	64	54	60	42	51	53	42	40	28.5	34	34.5	33
14	70	83	72	57	73	72	47	57	58	44	63	60	12	28	26.5	24	20	15
15	62	68.5	72	62	74	69	50	59	61	50	70	67	28	31.5	34	6	17	17
16	69	76	79	57	61	67	59	70	72	57	60	55	36	43	38	11	26	25
17	79	88	88	62	73	73	65	78	72	41	56	56.5	31	39	35	11	35	31
18	75	89	91	61	74	74	69	79	77.5	56	65	65	35	37.5	34	20	30	34
19	80	89	85	61	71	72	63	76.5	76	57	60	54	34	30	28	35	38.5	36.5
20	70	76.5	78	61	71	77	63	72	69	61.5	56	48	21.5	29	25	35	41	36
21	62	72	74	65	81.5	82.5	55	73	71	36	42	42	21	39	34	36	42	42
22	64	75	79	71	85	84	62	75	75	38	44.5	41	26	45	39	40	40	38
23	63	72	69	65	77	81	56	63	62	35	46.5	45	35	56	52.5	34	35	34
24	64	73	73	69	82	69	50	66	67	48	52.5	47	41	56	55	24	28	26
25	60	69	73	59	72	70	48	55	54	37	41.5	35	41	42	41	27	28	27
26	64	73	77	60.5	76	67	40	52	56	22	43	43	39	43	40	31	38	39
27	60	76	79.5	60	70	70	46	61	66	40	50	48	36	36	31	35	48	41
28	64	78	82	52	70	68	52	76	76	40	47	42	31	32	39	33	45	44
29	63	67	75	63	76	78	55	72	77	31	38	36	49	54	46	37	44.5	41
30	64	75	70	72	74	78	58	80	83	23	42	41.5	16	17	15	32	32	31
31	62	63	67	61	68	71	.....	.....	.....	40	40	40	.....	.....	.....	28	35	34
Averages	67.9	77.5	77.1	64.3	75.5	75.7	57.4	68.6	69.0	46.4	57.4	55.0	33.9	40.9	37.6	28.6	34.3	32.7

READING OF MAXIMUM AND MINIMUM THERMOMETERS FOR 1905.

DATE.	JANUARY.		FEBRUARY.		MARCH.		APRIL.		MAY.		JUNE.	
	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.
1	49	36.5	25	3	27	11	54	31	51	33	72	40
2	44	32	22	3	28	11	44	26	50	29.5	70	50
3	32.5	10	8.5	2	34	13	55	25	82	40	70	44.5
4	10	4	13	0	34	15	70	43	80	43	70	40.5
5	20	1	17	—6	34	1	57	38	70	48	80	58
6	31	8	31	9	28	14	48	32	72	51	76	53
7	33	21	23	10	35	9	43	29	68	56	59	52
8	26	19	19	—4	35	29	41	28	75	39	68.5	42
9	23	16	37	10	40	14	62	34	74	41	79.5	44
10	27	14	37	21	38	22	65	45.5	63	40	80	58
11	19	14	21	10	29	9	51	41	70.5	39	74	60
12	43	16	30	7	29	11	54	31	78	55	78	62
13	37	15	26	5	29	11	65	31	78	50	76	58
14	15	5	13	—6	30	9	59	31	78	52	83	54
15	16	—1	15	8	35	2	43	29	73	59	87	56
16	23	13	22	—1	32	13.5	40	23	68	49	83.5	65
17	27	19	30	19	45	22	40	27	73	52	84	67
18	35	7	27	10	53	37	38	27	68	49	83	63
19	40	30	28	4	54	27	55	26	64	48	90	64
20	35	26	45	18	29.5	26	59	43	58	37	89	61
21	32	21	44	30	34	27	54	32	66	40	87	66
22	31	19	35	23	44	29	51.5	29	63	38	76.5	65
23	20	11	35	26	46.5	34	53	31	59	38	74	55
24	23.5	2	37	15.5	49	37	63	30	72	35	80	54
25	23	7	38	11	55	36	61	34	79	51	84.5	58
26	8	—2	36	20	59	31	66	36	77	59	81	54
27	24	4	30	12	59	42	65	47	70	50	65	50
28	23	12	31	20	75	35	75	45	72.5	43	74	52
29	20	4	....	....	82	48.5	75	50	74	49	78.5	56
30	24	3	....	....	77	49	63	40	70	49	82	52
31	23	4	....	....	66.5	36	....	....	70	40	....	....
Averages	27.0	12.6	27.7	10	43.4	22.9	55.7	33.8	69.9	45.2	77.8	55.1

READING OF MAXIMUM AND MINIMUM THERMOMETERS FOR 1905—(*Concluded*).

DATE.	July. 5 P. M. Max.	July. 5 P. M. Min.	August. 5 P. M. Max.	August. 5 P. M. Min.	September. 5 P. M. Max.	September. 5 P. M. Min.	October. 5 P. M. Max.	October. 5 P. M. Min.	November. 5 P. M. Max.	November. 5 P. M. Min.	December. 5 P. M. Max.	December. 5 P. M. Min.
1	79	60	72	54	74	53	85	54	47	31	27	8
2	78	60	76	51	74	55.5	82	58	43	28	40	21
3	85	57.5	80	48	83	65	76	50	43	27	42	31.5
4	84.5	65	85	50	79	60	80	55	48	36	34	21
5	80	62	84	60	71.5	55.5	75.5	60	49	30.5	28	18
6	85	67	84	61	70	57	64	40	52	37	37	25
7	83	68	82	62	74	56	65	35	44	37.5	48.5	34
8	86	66	83	64	74.5	52	79.5	42.5	44	33	44	31
9	86	65	85	58	79	46	81.5	57	42	30	42	34
10	83	62	93	67	79.5	57	75	49	41.5	30	39	22
11	88	60	84	70	72	60	70	44	50	30	37	22
12	88	69	86	68	71.5	57	52.5	41	61	41	45	33
13	87	65	83.5	60	71	53	56	39	56	28	40	30
14	85	62	76	51.5	62	36.5	67	42	32	11	33	14
15	76	60	79	59	61	42	77	45	35	22	23	1
16	79	56	70	56	75	56	68	55	45	32	33	4
17	91.5	63	76	48	80	62	61.5	40	40	30	40	10
18	92	68	76.5	50	84	65	65	47	40	33	34	16
19	91	75	74	53	86.5	59	65	53	34.5	27	39	33
20	85	64	82.5	59	77	62	62	47	32	20	43	33.5
21	79	55	85	55	77	48	48	35	43	19	43	33
22	81	48.5	87	65	79	56	46.5	33.5	49	23	45.5	37
23	79	62	84	56	75	51	48	32.5	59	30	38	32
24	77	61	83.5	59	70.5	48	53.5	41.5	60	38	34	22
25	74	56	74	56	67	42	48	35	59	38.5	29	22
26	77	54	79	58	58	36	49.5	20.5	45	30	45	25.5
27	80	55	71.5	41	69	37	51	36	41	31	52	33
28	83.5	54	74	48	80	48	48	38	39	24	50	30
29	82	62	80	59	82	58	42	28	56	38	52.5	36
30	77	63	81	65	88.5	45	50	22	46.5	14	41	30
31	71	60	78	59	....	....	46	35	....	....	36	25
Averages	82.3	61.4	80.3	57.1	74.8	52.6	62.5	42.3	45.9	29.3	39.2	24.8

SUMMARY OF MAXIMUM, MINIMUM AND STANDARD AIR THERMOMETERS FOR 1905.

	Maximum.	Minimum.	Standard.		
			7 A. M.	12 M.	5 P. M.
	Average.	Average.	Average.	Average.	Average.
January	27.0	12.6	19.1	21.8	19.7
February	27.7	10.0	14.9	22.2	21.4
March	43.4	22.9	27.1	37.3	37.4
April	55.7	33.8	39.0	49.4	48.6
May	69.9	45.2	52.6	62.7	63.4
June	77.8	55.1	62.3	71.6	71.7
July	82.3	61.4	67.9	77.5	77.1
August	80.3	57.1	64.3	75.5	75.7
September	74.8	52.6	57.4	68.6	69.0
October	62.5	42.3	46.4	57.4	55.0
November	45.9	29.3	33.9	40.9	37.6
December	39.2	24.8	28.6	34.3	32.7

INDEX

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B.

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M.

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P.

T.